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Alternative future scenarios for open space protection in Kane County, Illinois

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PREFACE

My initial interests upon entering the Department of Landscape Architecture at Iowa State University were focused on finding a way to study large scale landscape design and natural resources conservation via the use of Geographic Information Systems (GIS). I was introduced to Oregon's Willamette River Basin alternative futures project during one of my initial visits to the Department. I realized the value of this large scale planning and decision-support tool, but also realized it would be very difficult to implement on my own. Based on this I decided to attempt a similar project, essentially by myself, to see if and how this tool could be used by smaller organizations who may wish to complete their own studies.

During the conceptual phase of the project we were granted funding by the United States Forest Service to work with them on a spatial modeling project focused on site suitability modeling for conservation in the Chicago region. Kane County, Illinois, was selected as the specific target location of this study for two primary reasons: first, they fit the criteria as a rapidly urbanizing county near Chicago who was attempting to acquire open space, and secondly because they had existing GIS data that they allowed us to use.

Work was completed primarily in ArcGIS 9.x, as during my time working on the GIS aspect of this project a new version of the software was released. An original thought of this project was that a more portable model would be useful if others wanted to use it themselves. That said, it was found early on that ArcGIS had several issues automating the model, making this less important or likely as time went on. The results of this project are included in the body of the following thesis.

CHAPTER 1. GENERAL INTRODUCTION

As metropolitan areas expand they exert development pressures on the surrounding landscape. Kane County, Illinois, located on the western fringe of greater Chicago, is currently experiencing the extreme growth rates characteristic of many rapidly urbanizing areas in the United States (Sierra Club 1998, 1999). Rapid increases in land consumption, typical of sprawl development, have led to increases in property values and have limited the ability of conservation organizations to plan for and to preserve open space (McMillen 1996, Schmidt 1998). In order to mitigate many of the negative social and ecological effects of sprawl, organizations need to acquire open space while it is still available (Theobald et al. 1997, Schmidt 1998, McKinney 2002, Kaplan and Austin 2004, Sturm and Cohen 2004).

The Kane County Forest Preserve District (FPD) is a local government agency responsible for the acquisition and maintenance of open space. The FPD currently uses an ad hoc approach to open space acquisition that reflects a series of specific conservation goals and evaluates parcels as they become available (Kane County 2005). A more structured approach would provide a road map for planners to better understand the long-term costs associated with specific conservation goals over time and thus more effectively strategize their land conservation (Pressey 1994).

The study of alternative futures was first developed as a decision-making tool to explore land use change over time in large geographic areas (Steinitz 1990, Baker et al. 2004). However, most studies that have used this technique were well-funded and required large teams of researchers (e.g., Nassauer et al. 2003, Steinitz et al. 2003, Baker et al. 2004). Through our focused approach to alternative futures we created several scenarios to identify costs associated with acquisition, restoration, and long-term maintenance of conservation lands in Kane County. In addition, we identified differences among scenario outputs based on quantity and location of conserved land. We evaluated these scenarios through a framework for alternative futures modeling in ArcGIS 9.0 (ESRI 2005) that accounted for urban growth as well as conservation site suitability based on existing policy and acquisition goals of the Kane County FPD.

Thesis organization

This thesis comprises a literature review and one paper written for publication in the journal Landscape and Urban Planning. Chapter 1 contains a general introduction of my thesis research. Chapter 2 is the literature review. Chapter 3 is an exploration of alternative future scenarios for open space protection in Kane County, Illinois, and the costs associated with implementation of different conservation goals. Chapter 4 contains general conclusions from my thesis research. Appendix A includes a more in-depth account of the methods used in this research.

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CHAPTER 2. LITERATURE REVIEW

Introduction

In this chapter I review literature related to the major themes of my research. First, I explore urbanization in North America and the effects it has on the environment and society. Next, I discuss two tools, scenario planning and alternative futures studies, which are widely used in growth management and conservation planning. The final section describes concepts that are fundamental to spatial modeling using GIS, particularly as it pertains to urban growth and conservation planning.

Urbanization

In the late 1940's a series of government policies stimulated a shift from urban to suburban living in the United States. Public Works road-building projects were greatly expanded and the Servicemen's Readjustment Act of 1944, or G.I. Bill of Rights, provided subsidies to veterans for purchasing new homes. In addition, the increased affordability of the automobile helped provide the middle class with easier access to life in the suburbs (Sierra Club 1999). Between 1930 and 2000 the percentage of Americans living in metropolitan areas nearly doubled to 80% of the country's population. During this time the percentage of Americans living in central cities, or the largest city inside a metropolitan area, has remained fairly constant at approximately 31%. In comparison, the portion of the population residing in suburban areas, or areas inside of metropolitan areas excluding the central city, increased from 14% to 50% living in suburban areas. Between 1990 and 2000, the percentage of Americans living in suburbs increased by 4%, compared to a decrease of 1.3% of those living in cities (Hobbs and Stoops 2002). Although this movement seemed positive at its onset in the 1940's, it was the beginning of a trend that continues today and carries with it many negative consequences.

Unchecked suburban development can turn into "sprawling development" (Schmidt 1998). Sprawl, as it is often termed, is a type of suburban development that has no single agreed-upon definition. The Sierra Club (1999, p.1) considers sprawl to be "low-density, automobile-dependent development beyond the edge of service and employment areas." Ewing defines it as a combination of

> (1) leapfrog or scattered development; (2) commercial strip development; and (3) large expanses of low-density or single-use developments - as well as by such indicators as low accessibility and lack of functional open-space. (1997, p.32)

The US Department of Housing and Urban Development defines sprawl as

> a particular type of suburban development characterized by very low-density settlements, both residential and non-residential; dominance of movement by private automobiles, unlimited outward expansion of new subdivision and leap-frog development of these subdivisions; and segregation of land uses by activity. (USHUD 1999, p.33)

Based on these definitions I have characterized sprawl as scattered, automobile dependent, low-density residential or non-residential development which consumes large areas of land and limits open space.

Sprawl has been linked to numerous adverse environmental effects. Between 1992 and 1997, sprawl resulted in the development of 2.2 million acres of land per year on average, a marked increase from 1.4 million acres per year between 1982 and 1992 (NRCS

2001). Due to sprawl's high rates of land consumption, it has been identified as a leading cause of habitat fragmentation and degradation (Theobald et al. 1997, Czech et al. 2000, Johnson 2001, McKinney 2002). In addition, it fosters biotic homogenization through the removal of native species and introduction of nonnative and invasive species (Blair and Launer 1997, McKinney 2002). Blair and Launer (1997) found an increased number of nonnative species closer to urban centers concurrent with a decrease in native species.

Increased road construction resulting from the scattered, car-dependent nature of sprawl has resulted in higher rates of road-kill, leading to the death of an estimated one million vertebrates daily in the United States (Forman and Alexander 1998, Clevenger 2003). Forman and Alexander (1998) approximate that there are 6.2 million km of roads in the United States, covering approximately 1% of the country's total area. They also estimate that these roads have negative ecological impacts on up to 20% of the total land area of the United States. In addition to roads, low density housing, strip development and other paved areas have increased impervious surfaces, which are linked to increased runoff and water pollution (Arnold and Gibbons 1996, Adelmann 1998, Forman and Alexander 1998, Johnson 2001, Stone 2004). Reliance on automobiles also has been linked to increases in air pollution, contributing up to 35% of direct particulate matter emissions, which are directly correlated with global warming and numerous respiratory problems (Johnson 2001, Buckeridge et al. 2002, Litman 2003, Sturm and Cohen 2004).

Open space provides refugia for species that may not be able to subsist in an otherwise urban or suburban matrix (Marzluff et al. 2001). The larger the area, the more it is able to reduce fragmentation and edge effects (Theobald et al. 1997, Czech et al. 2000, Johnson 2001, McKinney 2002). One specific example for the need of larger contiguous areas is described by Herkert and others (2003) who concluded that grassland birds require areas larger than 100 ha to increase nesting success.

Open space reserves, broadly defined as lands not devoted to urban development, are important not only for the protection they afford rare species and ecosystems but also for the educational and recreational opportunities they provide urban residents (Miller and Hobbs, 2002). For example, increased road congestion caused an increase in commute times of 59% between 1980 and 1995 (Schmidt 1998). In a study of residents of West Palm Beach, Florida, those in sprawling suburban areas were 40% more likely to have a variety of obesity and inactivity related medical conditions than persons living in the urban center (Warner 2004). Research conducted by Ewing and others (2003) found a direct correlation between living in sprawling suburban areas and decreased levels of physical activity. They also found direct correlation between increased rates of obesity and hyper-tension, which in turn lead to higher rates of diabetes, colon cancer, osteoarthritis, osteoporosis, and coronary heart disease.

Open space benefits both the physical and mental health of humans, as it offers relief from the stresses of every-day life and a recreational antidote to sedentary lifestyles (Stewart and Krieger 1999, Miller and Hobbs 2002, Kaplan and Austin 2004). People wishing to get away from the cluttered, over-stimulated nature of everyday life often seek more simplistic natural settings (Kaplan and Kaplan 1989). Access to open space has been found to relieve stress, stimulate higher cognitive function and enhance observational skills (Kaplan and Kaplan 1989, Ulrich et al. 1991, Miller 2005). From a physical standpoint, increased activity due to recreation lessens the negative health impacts of a living in a sprawling area noted by Warner (2004) and Ewing et al. (2003). These areas lessen many of the aforementioned negative effects of sprawl by acting as oases in an otherwise developed landscape.

Scenario Planning

Scenario planning is the creation and use of distinct, contrasting scenarios to explore possible outcomes of a particular planning decision (Coates 2000, Peterson et al. 2003). Herbert Kahn is credited with the initial development and use of scenario planning as a researcher with ties to the U.S. military in the 1960's (Peterson et al. 2003). This particular use of scenario planning focused on forecasting future possibilities for the outbreak of nuclear war, and more specifically on identifying strategies to mediate possible negative outcomes (Kahn and Wiener 1967, Peterson et al. 2003).

Peterson and others (2003) describe a multi-step approach to scenario planning beginning with the identification of the key topic or concern. The socio-economic and ecological contexts in which decisions are made are assessed to identify the factors necessary for scenario construction. Those factors are considered and alternatives are developed to address the effects of different possible decisions. Scenarios are then tested and qualitatively and quantitatively assessed and redefined, if needed, before they are finalized. The end result is a set of scenarios that can be used to help assess and guide policy change and predict, rather than shape, the future (Jouvenel 2000).

Since their introduction in the 1960's, scenarios have been used as a planning tool in several disciplines. In the early 1970's, the Shell Oil Company applied scenario planning to evaluate their business practices and plan for shortages of crude oil (Wack 1985). In the 1990's, a group of leaders from South Africa with help from advisors from Shell Oil utilized this tool to strategize possible political futures for the country (Kahane 1992, Peterson et al. 2003). This study considered differences in minority and majority rule, as well as the continuation or ending of apartheid.

Scenario planning was not applied to ecological and conservation issues until the 1990's. In an investigation of the Northern Highland Lake District of Wisconsin, Peterson et al. (2003b) derived distinct contrasting scenarios to help evaluate possible policies for their ecological risks versus economic benefits. This study took place in a rapidly developing area where tourism was an important aspect of the economy, and explored degradation of water quality and fish populations. The focus was on how the reduction in quality of these natural areas impacted perception of recreational value, and how identifying these issues may help to increase awareness and support for conservation in the area while still maintaining their economy.

Lee and Thompson (2002) created scenarios to identify areas for nature reserve creation to add to a European conservation network. These sites were targeted based on several ecological criteria including patch size, perimeter-to-area ratios, connectivity, and biodiversity. For this study 10 scenarios were created to prioritize areas using specific conservation criteria. An additional 40 random scenarios were developed by prioritizing sites arbitrarily, without regard for conservation goals. These random scenarios were used to represent an ad hoc approach to site selection, for comparison to the 10 focused conservation scenarios. The researchers found that the targeted or planned method was in fact more beneficial to biodiversity and habitat sustainability than an ad hoc approach; by planning for specific goals, these methods could allow for a more effective means of reducing fragmentation and adverse anthropogenic effects.

Scenario planning is useful in conservation planning due to its ability to handle uncertainty through consideration for alternative possibilities (Peterson 2003). It is not feasible to conduct experiments at large regional scales, as there are too many confounding variables that make replication impossible. This experimental framework relies on models to simulate the effects of planning decisions where otherwise implementation, for the sake of comparison, may not have been possible. Alternative perspectives are developed to return a comprehensive set of possibilities because:

> The central idea of scenario planning is to consider a variety of possible futures that include many important uncertainties in the systems rather than to focus on the accurate prediction of a single outcome. (Peterson et al. 2003, p.359)

The same is true for resilience to unforeseen events; given the ability of scenario planning to adjust to changes, it is an adaptive process that is intended to be used and continuously improved. By preparing for only one desired outcome, without consideration for unplanned events, one would vastly decrease the probability for success.

Alternative Futures

Alternative futures analysis is a focused approach to scenario planning which originally evolved from the fields of Landscape Architecture and Environmental Planning. This approach was developed as a decision-making tool for long term, large geographic scale projects allowing planners to assess future possibilities for water and land use (Steinitz 1990, Baker et al. 2004). Through the use of Geographic Information Systems, these studies incorporate spatial modeling and typically include a variety of visualizations to help guide planners and educate stakeholders (Steinitz 2003). The study of alternative futures provides...

a long-term, large area perspective on the combined effects of multiple policies and regulations affecting the quality of the environment and natural resources within a geographic area. (EPA 2002, p.1)

The United States Environmental Protection Agency (EPA) describes alternative futures as a three-step process (EPA 2002). First, document current and historic landscapes and identify possibilities for change. Second, develop two or more alternative scenarios for the possible future of the landscape. Finally, evaluate the expected effects of each alternative future from ecological and socio-economic viewpoints.

Among the first examples of alternative futures studies include the work of Carl Steinitz. Steinitz, of Harvard University's Department of Landscape Architecture, is largely credited with the development of the alternative futures research framework (Steinitz 1990, 1994). Steinitz and others (1994) examined alternative futures for Monroe County, Pennsylvania, to address the issue of land conservation in a rapidly urbanizing area. This project identified six unique alternative futures for 2020, each assessing a different land management strategy for the area. The research focused on urban growth, possible effects of development, and possibilities for management in the Monroe County region. Geologic, biologic, visual, demographic, economic, and policy data were incorporated in this research. This team-based approach was Steinitz's first broad-scale study to use a large team of researchers and an extensive database.

Steinitz et al. (1996) conducted a similar project focused on Camp Pendleton, California that explored the various ways that urban growth might influence biodiversity in this region. Expanding on previous efforts, this work included researchers representing a wide range of expertise from Utah State University, the National Biological Service, the U.S.

Forest Service, the U.S. EPA, the Nature Conservancy, and Oregon State University's Biodiversity Research Consortium. This team of researchers was able to investigate thoroughly key aspects of a large, diverse data set and focused on ways of minimizing the impacts of rapid urbanization on biologically diverse natural areas.

More recently, Steinitz and others (2003) explored possible futures for the Upper San Pedro River Basin of Arizona and the Sonora Desert. This region was targeted, in short, due to its ecological sensitivity and its value as a diverse and rare ecosystem. Like the Camp Pendleton project, this effort also included experts from different fields including researchers from Harvard University, the University of Arizona, and the Desert Research Institute. This study typified Steinitz's catalogue of projects in that it was very comprehensive and considered urban growth, land use, hydrology, vegetation, ecology, biodiversity, and the visual preferences of stakeholders.

The EPA funded a broad-scale alternative futures exploration of the Willamette Basin of Oregon (EPA 2002, PNERC 2002). This work was conducted by the Pacific Northwest Ecosystem Research Consortium (PNERC) which included researchers from the University of Oregon, Oregon State University, and the University of Washington. The primary goal of the PNERC was to develop an approach to evaluating alternative futures, as well as to understand ecological processes in the Willamette Basin (Hulse et al 2002). This project identified possible futures for this region for the years 2025 and 2050 and used historic data to model pre-settlement conditions. Unlike the previously described studies, the Willamette work included very large quantities of historic data to help guide the analyses. The investigation focused on land-use regulations and consisted of three scenarios: "trend", which depicted futures as they would be under current regulations; "development", which gave limitless authority to urban growth in the region; and "conservation", which focused on decreased development and increased land conservation (Baker et al. 2004, Berger and Bolte 2004, Hulse et al. 2004).

In comparison to other comprehensive studies, Nassauer and others (2002) employed a more focused alternative futures approach. Like others, this research was funded by the EPA and used stakeholder participation to help guide scenario construction. Three possible futures were explored by creating landscape scenarios to theorize possible changes in agricultural policy based on production, water quality, and biodiversity. These studies were further developed to assess alternative futures for two agricultural watersheds in Iowa through 2025 (Santelmann et al. 2004). This research was subsequently expanded by Rustigian et al. (2003) to assess impacts of landscape design on amphibians in the same Iowa watersheds. This work provided rationale for focusing the alternative futures method; several specific questions were successfully answered with fewer resources than other previously-mentioned research.

Collectively, these studies are not an exhaustive representation of work that has been done in the area of alternative futures, but rather some of the more recognized examples addressing application of the method. Key aspects of these projects have helped shape and focus my own research. From these studies, researchers were able to provide various visualizations and recommendations for land use planning to those invested in helping their respective geographic regions. One unfortunate aspect of the previously mentioned research, however, is the lack of follow-up reports. The study commissioned by the EPA in Oregon did influence planning decisions; however, it is not clear whether the other projects have had significant impacts on planning in their respective regions. The main drawback of the alternative futures studies is that this method is still in its infancy and there has not been sufficient time to implement these findings, let alone explore their impacts.

GIS and Spatial Modeling

Models represent a simplified version of reality and are used to "analyze the past, define the present, and consider possibilities of the future" (Smyth 1998, p.191). Spatial models can be strictly mathematical or can integrate GIS. Tomlin (1990, p.168) describes modeling as being either descriptive or predictive; descriptive models attempt to describe "what is" or "what could be" in a location currently, whereas predictive models illustrate "what could be" or "what will be" at a later time. Aspinall (1993) describes one class of predictive models as attempts to envision likely effects of land use policy on future landscapes. The goal of this section is to provide a review of the studies that provided a conceptual foundation for the urban growth and open space modeling components of my research.

Predictive modeling is the backbone of many urban growth studies. These models seek to predict future urban expansion through a variety of specific methods. Lopez et al. (2001) explored the relationship between urban growth and population growth using a linear regression technique. This particular method provides a simple yes/no value to indicate probability of growth in a given area. More recently logistic regression methods have been applied to explorations and modeling of urban growth (Wu and Yeh 1997, Cheng and Masser 2003). These methods are advantageous in growth modeling, as they are better able to account for the complexity of the urban system which does not often follow normal assumptions.

Another form of predictive modeling is the cellular automata, which has recently become more popular as a means for modeling urban growth. This method uses historic data to determine a series of growth rules, rates, and patterns in which to base likelihood of development (Clarke et al. 1996, Wu 1998, Li and Gar-On Yeh 2000, Liu and Phinn 2003). Cellular automata models provide a dynamic approach not reflected in the regression technique and provides an effective means for simulating and comparing landscape change (Ward et al. 2000).

Kim and others (2003) developed another approach to growth modeling that used historic urban and rural land data coupled with a gravitational pull. Areas adjacent to existing urban centers were weighted to identify those areas most likely to become developed. This and the other aforementioned studies focused entirely on creating the best model for predicting growth of urban areas without consideration for other land cover or land use types.

Suitability modeling can be used to explore possibilities of land use and thus is particularly relevant to conservation planning. This technique of modeling seeks to identify the most suitable areas based on pre-determined criteria (Lanthrop and Bognar 1998, Johnson and Gillingham 2005). Woodhouse et al. (2000) explored the use of GIS to prioritize sites for acquisition in the United Kingdom with the goal of protecting certain species of birds based on species richness and rarity. Rickets and Imhoff (2003) prioritized 76 North American ecoregions for conservation based on plant and animal data comprising several thousand species and focused on richness, endemism, urban cover, and agricultural cover. Areas can be weighted for selection based on various political or ecological criteria in order to focus on identification of key sites or to design nature reserves.

According to Pressey et al. (1997) there are two main types of algorithms within models: those used for designing nature reserves, and others for richness and rarity. Richness algorithms focus on sites with large quantities of "unreserved" features, compared to rarity, which focuses on sites with unique features (Kirkpatrick 1983, Margules et al 1988, Pressey et al. 1997). Regardless of the specific algorithm used, or how areas or prioritized, Pressey (1994) acknowledges the negative impacts of an ad hoc approach on acquisitions because of its tendency to bias against certain types of valuable sites. Pressey and Taffs (2001) suggest prioritizing areas of high vulnerability or irreplacability according to vegetation loss from clearing and agricultural in New South Wales. Their approach attempts to identify those areas most in need of conservation before they are no longer available. Connectivity between adjacent areas, or expansion of existing preserves, is also sometimes a focus of conservation modeling.

Fischer and Church (2003) developed an iterative modeling approach to explore the concept of expanding existing nature preserves in the Sierra Nevada region of California. Their method focused new conservation around existing core sites to increase contiguous area. This technique used a mathematical model that prioritized biodiversity, habitat type and shared edges between adjacent polygons. Being an iterative approach, this allowed previously expanded areas to be considered on subsequent time-steps, allowing extents of core areas to be identified over time.

One study that focused specifically on conservation in an urbanizing landscape is that of Haight et al. (2005), who created a site selection model for the protection of open space in Lake County, Illinois, near Chicago. The model for this research prioritized species richness and public access as the primary criteria for open space conservation and focused on areas that were susceptible to being developed. Additionally, this work utilized a two-period, or iterative model which, in its second iteration, was able to incorporate previously protected areas.

The use of scenario planning in an alternative futures framework could provide planners several beneficial tools to deal with rapid urban development and conservation of open space. Larger, more comprehensive futures and focused urban growth studies often come with large price tags and time requirements. For a local government with limited funds, these types of studies may be difficult to implement.

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CHAPTER 3. ALTERNATIVE FUTURE SCENARIOS FOR OPEN SPACE PROTECTION IN KANE COUNTY, ILLINOIS

A paper to be submitted to *Landscape and Urban Planning*

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Abstract: Kane County is located on the western fringe of the greater Chicago metropolitan area. Development pressures there have caused rapid increases in land consumption and property values. The county's Forest Preserve District is actively purchasing land for conservation, but it is important to understand fully the long-term costs associated with specific conservation goals. We created 18 future scenarios to identify costs associated with acquisition, restoration, and long-term maintenance of conservation lands in Kane County. We evaluated these scenarios through a framework for alternative futures modeling in ArcGIS 9.0 that accounted for urban growth as well as conservation suitability based on predetermined acquisition goals. Long-term costs were found to be less in areas of the county with more available land compared to scenarios which included areas where initial acquisition costs were higher. Additionally, by focusing on these areas it is possible to build larger core reserves. The results of our project will foster explicit consideration of the long-term costs associated with conservation strategies in Kane County, Illinois, as well as similarly urbanizing areas in the United States.

1. Introduction

Sprawl is characterized as car dependent, low density, unplanned growth beyond the range of urban service and employment areas (Ewing 1997, Sierra Club 1999, USHUD 1999, Gillham 2002). This phenomenon has been found to contribute to habitat fragmentation, habitat degradation, decreased biodiversity, and introduction of exotic species (Blair 1997, Theobald et al. 1997, Czech et al. 2000, Johnson 2001, McKinney 2002). Sprawl also impacts human health, as pollution, long commute times, road congestion, and insufficient open space have been linked to increased stress and physical ailments (Sierra Club 1999, Miller and Hobbs 2002, Kaplan and Austin 2004, Sturm and Cohen 2004). To offset these effects, planners are utilizing an expanding set of growth management strategies including scenario-based planning and alternative futures analyses.

Scenario-based planning involves contrasting possible outcomes of a particular decision (Coates 2000, Peterson et al. 2003). In conservation planning, scenarios have been used to explore anthropogenic effects on natural areas and to identify areas suitable for acquisition as nature reserves (Lee and Thompson 2002, Peterson et al. 2003b). This method allows planners to explore relationships among key variables and utilize the resulting "possible" outcomes to inform the decision-making processes. Alternative futures studies use scenario-based planning to assess water and land use for large geographic areas over time, without having to implement those strategies first (Steinitz et al. 1994; 1996, Baker et al. 2004).

Alternative futures studies typically use spatial modeling and Geographic Information Systems (GIS) to identify a comprehensive set of possible outcomes for a given area (Steinitz et al. 1994; 1996; 2003). Many of these studies are conducted to identify the environmental effects of urban growth on a region (Steinitz et al. 1994; 1996; 2003, Brown 2000, Baker et al. 2004, Hulse et al. 2004). This method can be a powerful approach but, due to their comprehensive nature, requires substantial resources in terms of personnel, data, and funding.

The goal of this research was to explore tradeoffs among several possible alternative futures for open space acquisition in a rapidly urbanizing area in the United States. Specifically, our objectives were to identify alternative future scenarios for the quantity and location of open space for a suburban county near Chicago, Illinois, and to calculate costs associated with acquisition, restoration, and maintenance for these possibilities. We also sought to develop an approach to modeling alternative futures in a commonly available desktop geographic information system (GIS) software package that could aid in conservation planning and be used easily by government or non profit agencies with finite resources. Kane County, located on the western fringe of the greater Chicago metropolitan area, is an area currently experiencing the extreme growth rates characteristic of many rapidly urbanizing areas in the United States (Sierra Club 1998, Sierra Club 1999).

2. Methods

2.1. Study Area

Kane County, in northeastern Illinois, was historically dominated by prairie and forested ecosystems (Fig. 1). According to Kilburn (1959), the pre-settlement land cover of Kane County was approximately 56% prairie and 43% forest ecosystems. Savannas were also part of the regional land cover; however they were not delineated in historic data sets (Greenberg 2002). Between 1830 and 1860, prairie lands in Illinois were cleared for agriculture at the rate of 3.3% per year (Iverson 1991). Today less than 1% of pre-settlement prairie and 31% of pre-settlement wooded areas exist in the state of Illinois (Hansen 1986, Iverson 1991). Specifically, Kane County is estimated to have only 17% forested land; however, studies have shown that wooded habitat in this region increased by 17% between 1962 and 1985 (Hansen 1986).

In the early 1900's there was a shift from agriculture to urbanization as the leading source of land clearing in Kane County. Since the 1930's the outward expansion of Chicago has caused rapid increases in population and consumption of both remaining native areas and agricultural land (Sierra Club 1998). In 1870 the population of Kane County was approximately 39,000 which grew to 79,000 in 1900. By 1930 the county's population had expanded to 125,000 increasing to nearly 210,000 in just 30 years (Pfannkuche 2006). Between 2000 and 2030 the number of residents of Kane County is expected to grow from 400,000 to nearly 700,000 (NIPC 2003). Even more dramatically, the urban footprint is expected to expand from 16% of the county in 1998 to 52% in 2028, a 325% increase (Openlands 1999). As of January 2005, the majority of the developed land fell in the eastern tier of the county where once distinct cities now flow together seamlessly (Fig. 2). This pattern is expected to continue from east to west, and it is estimated that by 2030 the eastern and central tiers of the county will be urban, with only the western areas remaining primarily agricultural (Kane County Regional Planning Commission 2004).

Like Kane County, rapid urbanization is impacting much of the greater Chicago region. To offset these impacts, a group of organizations forming the Chicago Wilderness (http://www.chicagowilderness.org) focus on the preservation of open space in the region. The Kane County Forest Preserve District (FPD) is an extension of the local government and member of the Chicago Wilderness consortium responsible for the acquisition and maintenance of open space in Kane County. The FPD has recently taken a proactive approach to preserving undeveloped land in the county (Sierra Club 1998, Openlands 1999, Kane County 2005). Prior to 1999, the Kane County FPD had approximately 2833 ha of land set aside as open space. In 1999, the Forest Preserve District acquired $106 million through a county-wide initiative to purchase 2226 ha of open space over a five-year period, a 78% increase in total holdings. In 2005 an additional $70 million was allocated for the acquisition of additional open space in the county (Kane County 2005).

As development extends westward, agricultural land prices will escalate and limit the ability of public and private organizations to acquire and protect open space (McMillen 1996, Atack and Margo 1998, McDonald and McMillen 1998, Acharya and Bennett 2001). To provide insight on how best to meet the needs of open space conservation in Kane County, we created scenarios based on existing policy that allowed us to compare trade-offs between land quantity and location, and total cost for each potential future.

2.2. Scenarios

We developed a series of alternative scenarios to explore the effect of funding, the spatial and temporal distribution of open space over time, and the impact of differential weighting of conservation priorities. We considered the extent of existing developed land in Kane County, open space owned and managed by the county's Forest Preserve District (Fig. 3), recent acquisition history, and the District's current emphasis on acquiring land adjacent to existing conservation areas or bordering water bodies (Kane County 2005). We then created models to evaluate all possible combinations of these factors to understand potential interactions and to examine the resulting suite of future outcomes.

To explore interactions among factors, we used a three-level approach to scenario development which combined a single conservation funding scenario (primary), a secondary scenario weighting proximity to water or existing open space, and a tertiary scenario exploring differences in land availability. The primary scenarios (*high*, *trend*, and *low*) reflect the level of financial support for open space acquisition by identifying the total amount of land to be purchased per five-year period. We assumed that funding would not fall to pre-1999 levels and defined the primary scenarios as follows: for each five-year period, *high* mandated the acquisition of up to 2023 ha of open space, *trend* set a goal of 1214 ha, and *low* limited purchases to 405 ha.

The secondary scenarios identified the effects of trade-offs involved in differential weighting of parcels adjacent to open space and to water bodies (Fig. 4). The first scenario (hereafter, *open space*) weighted parcels near existing open space 2:1 over those adjacent to water bodies. The second scenario (hereafter, *water*) focused on proximity to water bodies and weighted those areas 2:1 over areas neighboring existing open space. The third scenario (hereafter, *equal weight*) weighted these two groups of parcels equally.

The tertiary scenarios explored issues of land availability within the county as a function of patterns of urban expansion. The county is divided into three distinct vertical "tiers" of townships, ranging from mostly urban in the eastern areas to mostly agricultural in the west (Fig. 5). Because of this we created the tertiary scenarios to reflect differences between these areas within the county. The first of these (hereafter, *western tier*) prioritized conservation in the western third of the county by concentrating all acquisitions to that area. This prescript was meant to address the consequences of acquisitions focused where there is less development and land is less expensive. The second scenario (hereafter, *county-wide*) weighted all geographic locations within the county equally, thus providing a basis of comparison for the *western tier* scenario.

2.3. Data

We used a series of vector layers provided by the Kane County FPD as our primary GIS data sources (KCGIS 2005). Urban and non-urban land use was determined from a digital parcel layer containing zoning classification. All residential, industrial, or commercial parcels were grouped into an "urban" class, where other parcels were classified as "non-urban". Collectively, "urban" areas served as a baseline layer for urbanized area in 2005 and the remaining parcels were considered "available" for acquisition or development.

We used a comprehensive "water" layer consisting of lakes, rivers, streams and wetlands to address proximity to water. All types of water bodies were given equal weighting, as there was not a specific variety cited by the county as being preferred. In addition, a layer containing locations of existing Forest Preserve District lands was used to define open spaces (KCGIS 2005).

An existing estimate of urban growth rates for Kane County was used as the primary means for calibration of the urban growth model. In a comprehensive study of the greater Chicago region, the Openlands Project (1999) predicted that developed land in Kane County would increase from 16% in 1998 to 52% in 2028. Based on this prediction, developed land was assumed to increase at a constant rate of four percent compounded annually and this figure was used to determine the total amount of urban land to be added in the county during each five-year time step.

2.4. Modeling Framework

Alternative futures models were constructed for both urban growth and open space acquisition. The bulk of the model construction was done using ModelBuilder, the internal graphical modeling interface for ArcGIS (ESRI 2005), as it allowed several of this program's tools to be streamlined into a single process. These models were designed to work in tandem and run in five-year time steps with urban growth occurring prior to open space acquisition in each period.

We assumed that new development was more likely to occur adjacent to existing urban areas (Kim et al. 2003). The likelihood that a parcel would be developed was therefore based on its Euclidean distance from existing urban development. In addition, undeveloped parcels inside municipal boundaries were weighted proportionately higher (25%) to reflect an increased likelihood of development in those areas (Fig. 6).

Euclidean distance was used to weight proximity to existing open space and water bodies. For the *western tier* scenarios, an additional weight was added to those westernmost townships to promote open space acquisition in those areas. Parcels selected for development or acquisition in a given time step were removed from the pool of available parcels.

Reserves that are more contiguous have benefits for biodiversity by reducing edge effects by buffering interior areas, and thus increasing the potential for population viability (Saunders et al. 1991, Collinge 1996, Helzer and Jelinski 1999). To identify scenarios that may be better suited to conserving land for species requiring larger, less fragmented preserves, we used a modified "Patton index" for all acquired parcels output by each scenario (Faeth and Kane 1978, Schmid-Holmes and Drickamer 2001, Barko et al. 2003). This index is a measure of the difference between the perimeter-to-area ratio of a given area compared to that of a circle, a value of 1. The higher the resulting value, the more edge there is in the scenario. This index is calculated as:

$$P/[2(\pi A)^{1/2}],$$

where P represents the total perimeter of land in a given scenario and A is the total area.

2.5. Costs

The total cost of implementing each scenario was based on land price, management and maintenance costs, after the 2030 time step, expressed in US dollars.

Land prices currently tend to be the highest in the eastern, more urbanized part of Kane County (Ed Leuer, Value Masters, Real Estate Appraisal, personal communication, October 29, 2004). Land values in this county reflect a general trend for parcels to be more expensive when they are in highly developed areas (McMillen 1996, Atack and Margo 1998, McDonald and McMillen 1998, Acharya and Bennett 2001). Real estate values have been described as a gradient of prices ranging from $121,000/ha, nearest the urban areas in eastern Kane County, to $17,000/ha at the western edge (Ed Leuer, Value Masters, Real Estate Appraisal, personal communication, October 29, 2004).

To identify costs of land for 2005, and changes in land value over time, we quantified a cut-off for "urban" versus "non-urban" land based on density of urbanized land. To do this we divided the county into 10 columns of equal width (east-west). We identified the location of the western-most urban column of the county and then interpolated prices between east and west to provide a gradient of land values. To account for increased costs over time, an average of the outputs from the urban growth models was taken and applied to the same method (Fig. 7). This method quantified a westward movement of the fringe, and allowed for land values to increase over time to correspond to this change (Fig. 8).

Since the pre-settlement environment of Kane County has already been largely modified by clearing for agricultural uses, there is little unaltered land still in existence. Because the Kane County FPD encourages the preservation and restoration of "historic resources and habitats", focus was placed on the restoration of feasible acquired land to prairie because it has not shown the same resilience as wooded vegetation in the region (Hansen 1986). This is not to say that the Forest Preserve District isn't interested in wooded areas, but rather this process is more specific to individual sites.

Restoration costs were calculated using information provided by two private firms specializing in prairie restoration with projects in the Chicago region (Applied Ecological Services, Brodhead, WI; Driftless Area Stewardship, Glenhaven, WI). We averaged estimates of the wholesale costs provided for various components of prairie management including seed, tilling, planting, mowing and burning and derived a total cost of \$4133/ha for "row-crop" parcels, and \$4752/ha for grasslands or pasture.

Encroachment of woody vegetation has negative effects for prairie structure and composition (Ryan 1986, Gibson and Hulbert 1987). Because of this, it is important to prevent prairie succession to woody vegetation by managing restored parcels. With a price of \$215/ha for each time step, maintenance was based on the previously mentioned costs of management techniques and included mowing and burning each field once during each five-year period. The combination of restoration and maintenance costs allowed for a comparison between allocating money for maximization of land, or for restoration of existing land.

3. Results

3.1. Scenarios

The overall amount of urbanized land in each of the county's three tiers was similar across all 18 scenarios. On average, 81% of the eastern tier was developed by 2030, compared to 59% and 29% in the central and western areas respectively. The *high* scenarios did yield some variation, which was likely due to displacement of newly developed land caused by differences in locations of acquired open space. In these scenarios urbanized land in the western tier ranges from 24% to 33% compared to a lesser range (± 5%) in the central and eastern tier.

The spatial distribution of open space was influenced most by the tertiary scenarios. The results from the *western tier* varied considerably between *high* (Fig. 9), *trend* (Fig. 10), *and low* scenarios (Fig. 11), ranging from 69% to 35% of the county's total open space being acquired in the western section. In contrast, the *county-wide* scenarios distributed open space much more sparsely in the western tier of the county, as low as 13%. Scenarios focused on *county-wide* acquisitions yielded much higher quantities of land in the central tier, up to 57% of total open space (Table 1).

The secondary scenarios played a somewhat lesser a role in determining future location of open space in Kane County. Unlike the tertiary scenarios, however, the differences between locations of existing open space and water scenarios are slight. It is likely that adjacency to water in the past had been used by the county as a criterion for the selection of new open space. This might suggest why the variation between *water* and *open space* scenarios was not substantial across tiers.

The "Patton index" values for the *western tier* scenarios were consistently lower, with ranging from 21 to 25. Conversely, the *county-wide* scenarios ranged from 26 to 35. *Open space* scenarios had the lowest average values (24.7), compared *equal weight* (25.7), and *water* scenarios which were only moderately higher (27.7). Additionally, *low* scenarios averaged the lowest index values (23.8), compared to *trend* (26.3), and *high* scenarios which again had only moderately higher values (27.7, Table 2).

3.2. Costs

Based on our method for quantifying a gradient of costs, we determined land values as a function of their distance from the area identified as the "urban fringe". This area was determined as falling between the fifth (19%) and sixth (35%) columns from the west, as there was a sharp increase in urban density between the two (Fig. 8). This area coincided with the location at which land values peaked in the county (Ed Leuer, Value Masters, Real Estate Appraisal, personal communication, October 29, 2004). Based on these numbers the cut-off for "urban" versus "non-urban" land for a given time-step was quantified as a density of 27%, as it was the midpoint between the densities of the fifth and sixth columns.

Cost of acquisition for each alternative future was influenced most by the tertiary scenarios, which weighted either parcels in the western part of the county or weighted all parcels equally. The combination of maximum funding levels and equal weighting of parcels across the county produced similar results under each of the three secondary scenarios, averaging a total of $1.03 billion (Table 3). Conversely, scenarios with maximum funding and focused on acquiring land only in the western tier of the county averaged $602 million for the same period. Scenarios with moderate funding levels and an equal focus on all parcels averaged $626 million for approximately 40% less land, which was more than the better funded *western tier* scenarios.

The tertiary scenarios were also the key factor influencing restoration costs. In contrast to purchase costs, restoration costs were higher in the *western tier* scenarios because there is a higher percentage agricultural land in those areas. The average cost of restoration in *high* scenarios was $38.3 million for *western tier* compared to $30.3 million *county-wide* scenarios.

The costs of long-term maintenance were considerably lower among the various scenarios and necessarily reflected trends in restoration costs. The average costs to maintain restored lands in the *western tier* scenarios were \$3.80 million for those with maximum funding levels. In comparison, similarly funded scenarios that focused on county-wide acquisitions cost only \$3.2 million.

The total costs for implementation of each alternative future represent the combination of acquisition, restoration and long-term maintenance expenses. The pattern for overall cost follows that of acquisition; although the prices to restore land in the western tier are more, they are not sufficiently more expensive to offset the difference in purchase price. The average costs to implement for a *high* scenario across the entire county averaged \$1.06 billion compared to only \$644 million if acquisitions were focused on the western tier of the county. In comparison, scenarios with moderate funding levels and focused on acquisitions across the entire county averaged \$645 million in total costs (Table 3).

4. Discussion and Conclusions

We used an alternative futures framework to compare the influence of several factors on the future extent of open space in a rapidly urbanizing environment. To maximize the applicability of this framework to planning in Kane County, we developed scenarios based on current FPD policies that govern the acquisition of open space. These scenarios took into consideration urban growth to improve the realism of our research by accounting for uncertainty of land availability. We identified the quantity and location of acquired open space, and estimated the monetary cost to implement each scenario.

Many previous alternative futures studies have been well-funded and taken teams of researchers years to complete (Steinitz 2003, Baker 2004). In comparison, our approach was intended to be less timely and less expensive. While other studies have taken a more focused approach to alternative futures, they have not done so to the extent of our research. Santelmann et al. (2004) focused on evaluating consequences of changes in farmland management on land cover. As opposed to more broad studies, this work focused on a specific set of trade-offs in potential agricultural policies and their effects on two watersheds in Iowa. As opposed to these studies, our method's narrower focus increases its direct applicability to planning for open space acquisition in areas experiencing development pressures. In areas where money is an issue, this approach provides an alternative to the more comprehensive futures studies.

An additional asset of our research was that we used a common desktop GIS software package, and this has several advantages. First, the widespread availability of ArcGIS would allow others to implement our methodology using existing software. Although other alternative futures studies also relied on GIS, they were not explicit in describing how their models were created, or what software was used, making their methods difficult to replicate. Another benefit of using our GIS application is the ease with which models can be updated as needed. If futures need to be reanalyzed to account for changes in an area, the reduced time and costs associated with these steps when using ArcGIS are an important asset.

Another unique aspect of our research was the approach of assessing how existing policy can be applied more effectively to open space conservation, in contrast to other research that taken a more comprehensive approach to the effects of urbanization on natural resources. Work done in the Willamette Basin of Oregon identified three contrasting scenarios for land use regulations by focusing on patterns of urban growth and conservation and their impacts on ecological processes in the region (Baker et al. 2004, Berger and Bolte

2004, Hulse et al. 2004). Steinitz et al. (1996) examined possible futures for Camp Pendleton, California with the directed goal of determining ways to minimize the impacts of rapid urbanization on biologically diverse natural areas. These studies more broadly addressed effects of urban growth on the environment in their respective areas; they did not, however, specifically focus on these conditions under existing policy. We applied our work to the policies in place for open space acquisition in Kane County and identified the costs related to specific conservation goals.

Cost is often a limiting factor in open space acquisition. We developed a cost gradient based on distance from the urban core to account for expected increases in the price of undeveloped land over time. Based on studies of urban land values, we assumed that proximity to existing urban land would be the primary variable influencing parcel price. Because long-term land availability is impossible to predict, the projected spatial extent of each scenario will not be completely accurate. Because land values have historic precedents which may make them easier to predict with accuracy over time, the total cost predicted for each scenario should not change considerably.

We evaluated trade-offs stemming from the spatial focus of different scenarios, as well as between overall financial costs. The secondary scenarios, or those focused on either land proximate to existing open space or adjacent to water bodies, did not yield substantially different outputs. Because of current open space acquisition policies, existing Forest Preserve District lands tend to mirror water bodies, thus effectively negating any influence of one secondary scenario over the other.

The differences between the *western tier* and *county-wide* scenarios were considerable. In the former, all open space was acquired in the western tier of the county because land in that area was less fragmented. This allowed much and larger more contiguous areas to be created. In comparison, the *county-wide* scenarios distributed the open space more evenly across the county. From a financial standpoint, areas in the western tier tend to cost substantially less than other areas in the county. Implementation of these scenarios comes with a total price that is much less than its county-wide counterpart and would allow much more land to be acquired per dollar spent. In comparison, scenarios focused on the western tier of the county have much higher percentages of agricultural land that can be restored. For these areas, restoration costs would be higher than other parts of the county. If the land will be used to maximize habitat, scenarios providing more land would be preferable. In contrast, if maximizing area or increasing public access were the desired effects, then restoration for the purposes of providing habitat would not be as important (Haight 2005).

The larger contiguous areas resulting from the *western tier* scenarios may have greater habitat value for biodiversity for some species, as these areas reduce fragmentation and edge effects (Theobald et al. 1997, Czech et al. 2000, Johnson 2001, McKinney 2002). One example for the need of larger contiguous areas is described by Herkert and others (2003) who concluded that grassland birds require areas larger than 100 ha to increase nesting success. Smaller areas are likely to function as habitat sinks, or areas where reproductive success is exceeded by mortality (Pulliam 1988). Alternatively, humans may benefit from access to open space as it provides both physical and mental benefits for those who utilize them (Stewart 1999, Miller and Hobbs 2002, Kaplan and Austin 2004, Miller 2005). Scenarios focused on acquiring land throughout the county would increase access of open space to more residents, but would not allow for the larger areas allowed by the *western tier* scenarios.

A final trade-off exists in whether to purchase properties and restore habitat or delay restoration until some later date. Larger quantities of land could be acquired if restoration was postponed and the properties left unmanaged until a later time. This is an important consideration in Kane County and other areas under extreme development pressures, as available land is in limited supply. The option to purchase land now and restore it at a time when land is no longer available for acquisition would add 650 ha, or 6.5% more open space under some *high* scenarios. Conversely, if the goal is to create areas to serve as habitat for particular species, it would be important to restore open space as it was acquired. This option would cost for each time-step, but could provide necessary habitat for those particular species of interest.

Although it is the standard in GIS software, ArcGIS does have limitations when applied to an alternative futures framework. Because it was not designed to work in an iterative study, there were difficulties automating transitions between time steps and between open space and urban models. We were able to streamline the models using ModelBuilder; however, some specific tools were unable to be used in sequence. Certain processes required human intervention to reduce error or because they were unable to be done within the ArcGIS software, thus increasing the time requirements of this project. To deal with this issue, we created our models in several distinct parts to account for necessary breaks without adding unnecessary extra time. The inability of the software to more fully automate this framework could be reduced in new versions of the software, or it may be possible to edit scripts outside of ArcGIS to better address these concerns.

Another limitation of this research is the generalized nature of the urban growth model. Our method works in Kane County as this region has a well-defined urban core in the east and an east-to-west development pattern (KCRPC 2004); however, it may not be as successful in areas with more complex urban networks. Various studies have focused solely on creating models to predict future patterns of development (Li and Gar-On Yeh 2000, Kim et al. 2003, Liu and Phinn 2003), and one of these techniques may provide a more accurate prediction of growth over time, depending on specifics of urban development in a region. Depending on specifics of urban development in a region, one of these techniques may provide a more accurate prediction of growth over time. If they are able to be incorporated into this framework, existing growth models may better represent possibilities for future urban extent.

To further expand on our research, additional data sources might be incorporated to address specific conservation goals. Natural Heritage data sets, which are available at the state level, identify the status and distribution of rare species or community types (Cort 1996). This information could be combined with our open space model to identify areas important to the preservation of particular species of interest. Other data sources could also be considered. For instance, land held in trust by non-profit (i.e. The Nature Conservancy, The Trust for Public Land), or other local and regional government institutions could be more beneficial for expanding the open space network of the county than focusing solely on expanding FPD lands. Input from citizens could be used to modify goals so as to reflect community values. When represented visually, results may be a useful means for garnering support from the community, which may lead to increased funding for open space acquisition or restoration (Tress and Tress 2003).

We developed and applied this alternative futures framework to a succinct group of core questions focused on open space acquisition in a rapidly urbanizing landscape. In dealing with urban growth and environmental concerns, our research provides guidance for prioritizing open space acquisition and conservation goals and acts as alternative to existing, more costly futures frameworks.

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Table 1: Predicted quantity of total acquired open space between 2005 and 2030, cumulative open space including land held prior to 2005, and percentages of open space per tier of Kane County, for each scenario in 2030.

Scenario			Acquired	Total	% of total open space by tier		
Level 1	Level 2	Level 3	(ha)	(ha)	West	Center	East
High	Open space	Western focus	10062	15540	69%	20%	11%
		County-wide	10040	15518	22%	54%	24%
	Water	Western focus	10108	15586	69%	20%	11%
		County-wide	10017	15495	20%	54%	25%
	Equal Weight	Western focus	10076	15554	69%	20%	11%
		County-wide	10082	15561	20%	54%	26%
Trend	Open space	Western focus	6019	11497	58%	27%	15%
		County-wide	6023	11501	19%	53%	28%
	Water	Western focus	6046	11525	58%	27%	15%
		County-wide	6055	11533	16%	57%	27%
	Equal Weight	Western focus	6009	11487	58%	27%	15%
		County-wide	6024	11502	17%	55%	28%
Low	Open space	Western focus	1975	7453	35%	41%	24%
		County-wide	1958	7437	14%	54%	31%
	Water	Western focus	2008	7486	35%	41%	24%
		County-wide	2010	7488	13%	56%	31%
	Equal Weight	Western focus	2008	7486	35%	41%	24%
		County-wide	2004	7482	14%	54%	31%

Table 2: The Patton index value for open space output for each scenario in 2030.

Scenario	Patton index value
Low, Open space, Western Tier	20.7
Low, Equal, Western Tier	20.9
High, Open space, Western Tier	21.2
Trend, Open space, Western Tier	21.2
Low, Water, Western Tier	21.8
Trend, Equal, Western Tier	22.0
High, Equal, Western Tier	23.1
Trend, Water, Western Tier	24.2
High, Water, Western Tier	24.9
Low, Open space, County-wide	25.4
Low, Equal, County-wide	26.4
Low, Water, County-wide	27.7
Trend, Open space, County-wide	27.9
Trend, Equal, County-wide	29.7
High, Open space, County-wide,	30.1
High, Equal, County-wide	31.9
Trend, Water, County-wide	32.6
High, Water, County-wide	34.9

Table 3: Results of all costs including, acquisition, restoration, maintenance, and total cumulative for all scenarios, sorted from most to least expensive.

Scenario	Acquired Land (ha)	Total Acquisition Cost (USD)	Restoration Costs (USD)	Maintenance Costs (USD)	Total Costs (USD)
High, Equal, County-wide	9669	1042338142	31289740	3161593	1076789475
High, Water, County-wide	9617	1040700775	31127953	3150233	1074978961
High, Open Space, County-wide	9728	1003881680	32331637	3167272	1039380590
High, Water, Western focus	10110	618404217	37919685	3854704	660178606
Trend, Water, County-wide	5776	636936926	18106782	1898461	656942169
High, Equal, Western focus	10079	604305447	37998330	3841488	646145265
Trend, Equal, County-wide	5698	626112897	17471730	1875743	645460369
Trend, Open Space, County-wide	5761	613651498	18186172	1894763	633732433
High, Open Space, Western focus	10067	583758627	38368362	3803751	625930740
Trend, Water, Western focus	6048	378507777	22258810	2303046	403069633
Trend, Equal, Western focus	6012	369596428	22333635	2307026	394237090
Trend, Open Space, Western focus	6025	348136740	22507599	2298747	372943086
Low, Water, County-wide	1887	212119109	5316860	635330	218071300
Low, Equal, County-wide	1868	207815578	5250618	639557	213705753
Low, Open Space, County-wide	1831	200454660	5192629	615121	206262410
Low, Water, Western focus	2010	124237260	7153778	797404	132188442
Low, Equal, Western focus	2010	123222960	7065119	764126	131052205
Low, Open Space, Western focus	1977	119035350	6983491	755368	126774209

Figure 1. The location of Kane County, Illinois, relative to the city of Chicago.

Figure 2. The extent of urbanized land, or parcels zoned residential, commercial, or industrial, in Kane County as of January 1, 2005.

Figure 3. The extent of open space owned by the Kane County Forest Preserve District as of January 1, 2005.

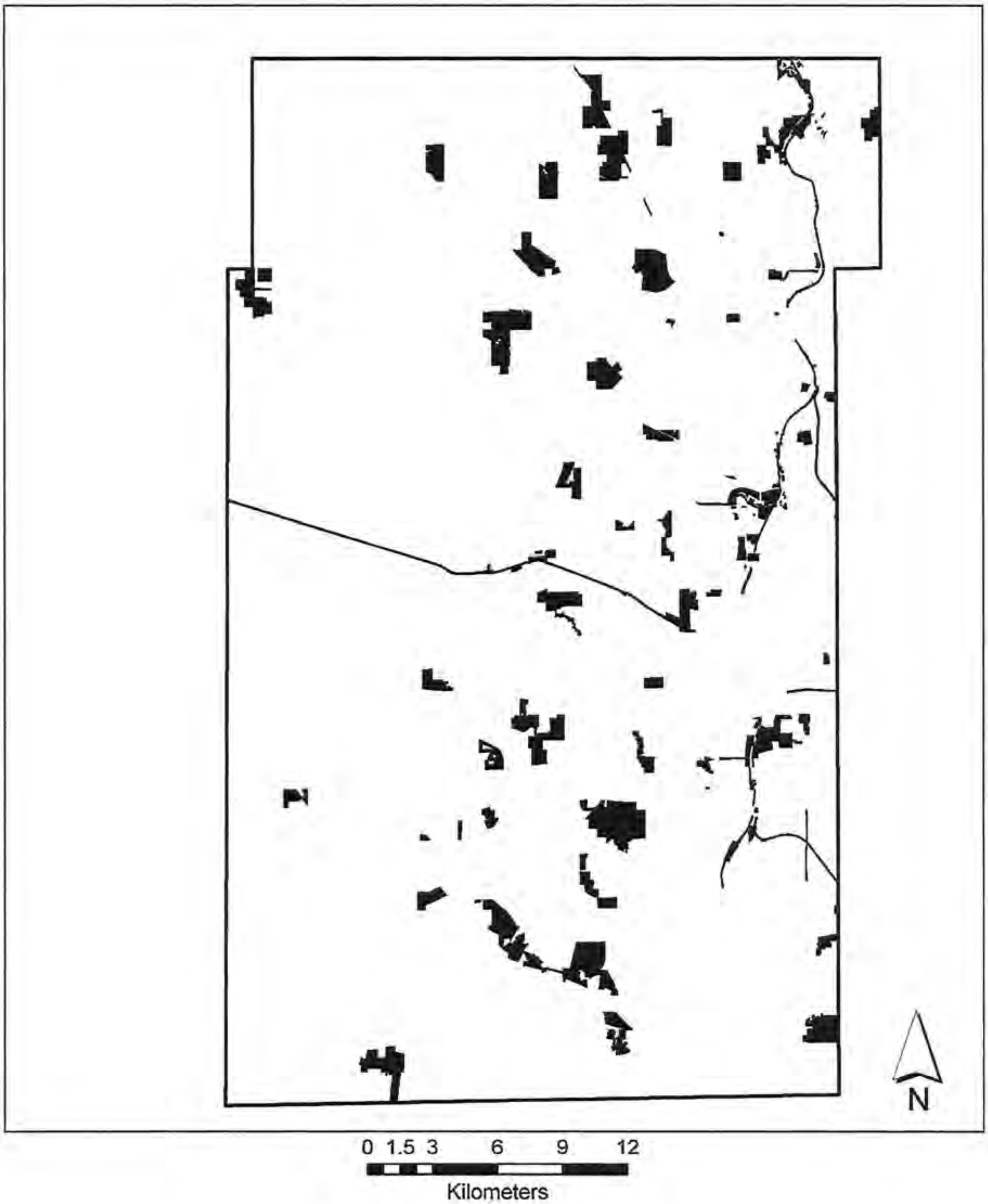


Figure 4. Water bodies of Kane County.

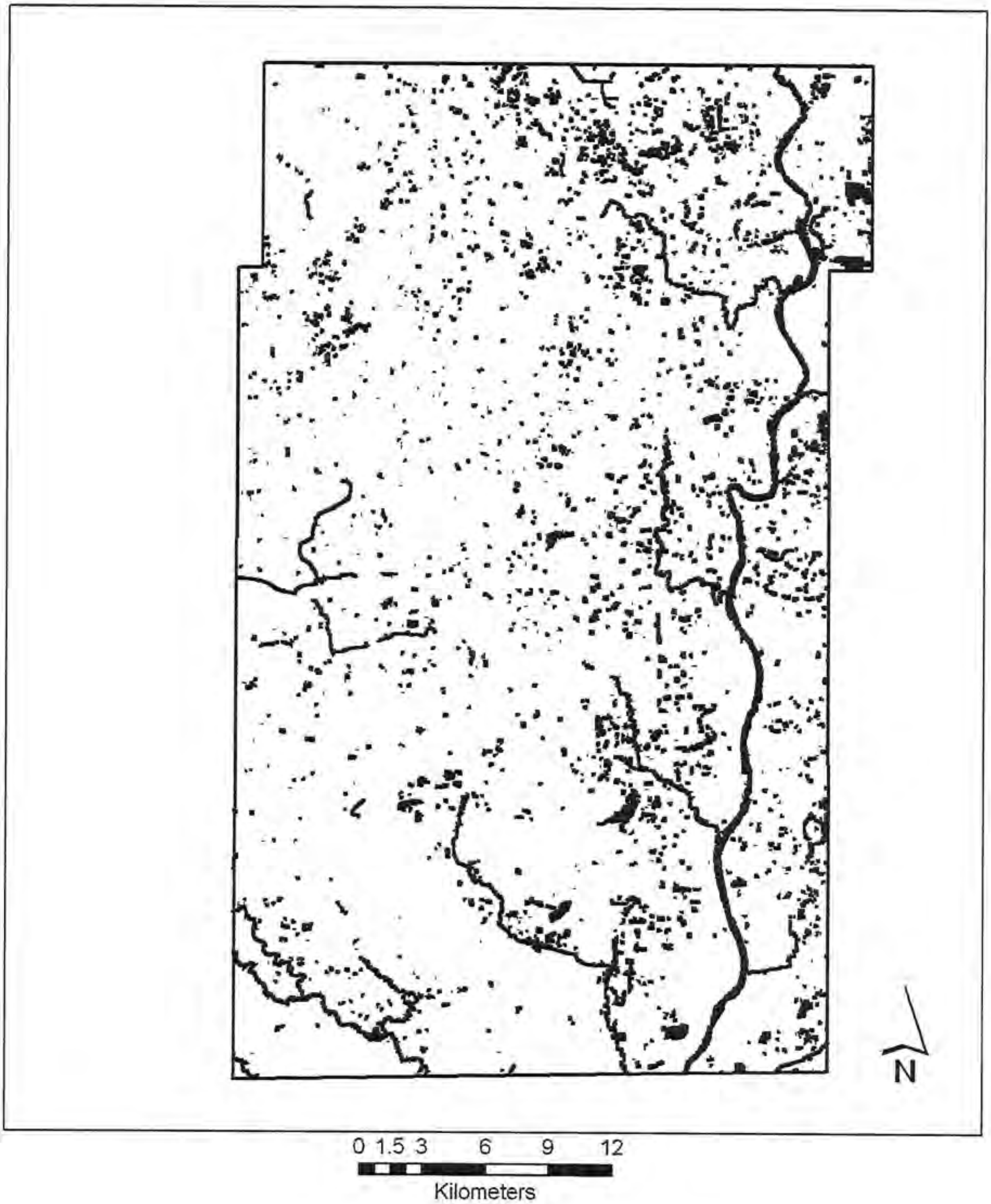


Figure 5. The three vertical tiers of Kane County: west, central, and east.

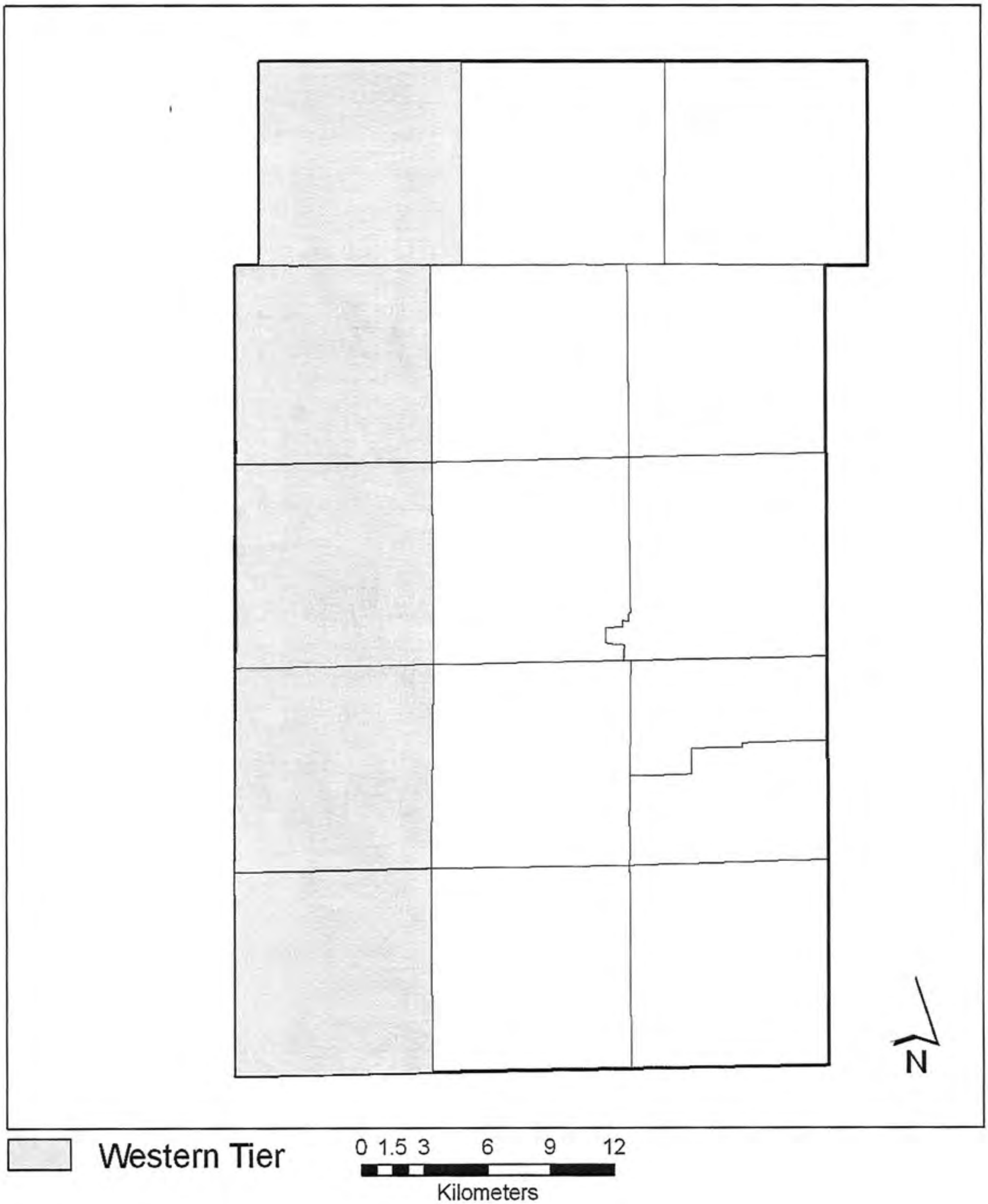


Figure 6. Boundaries of all municipalities in Kane County as of January 1, 2005.

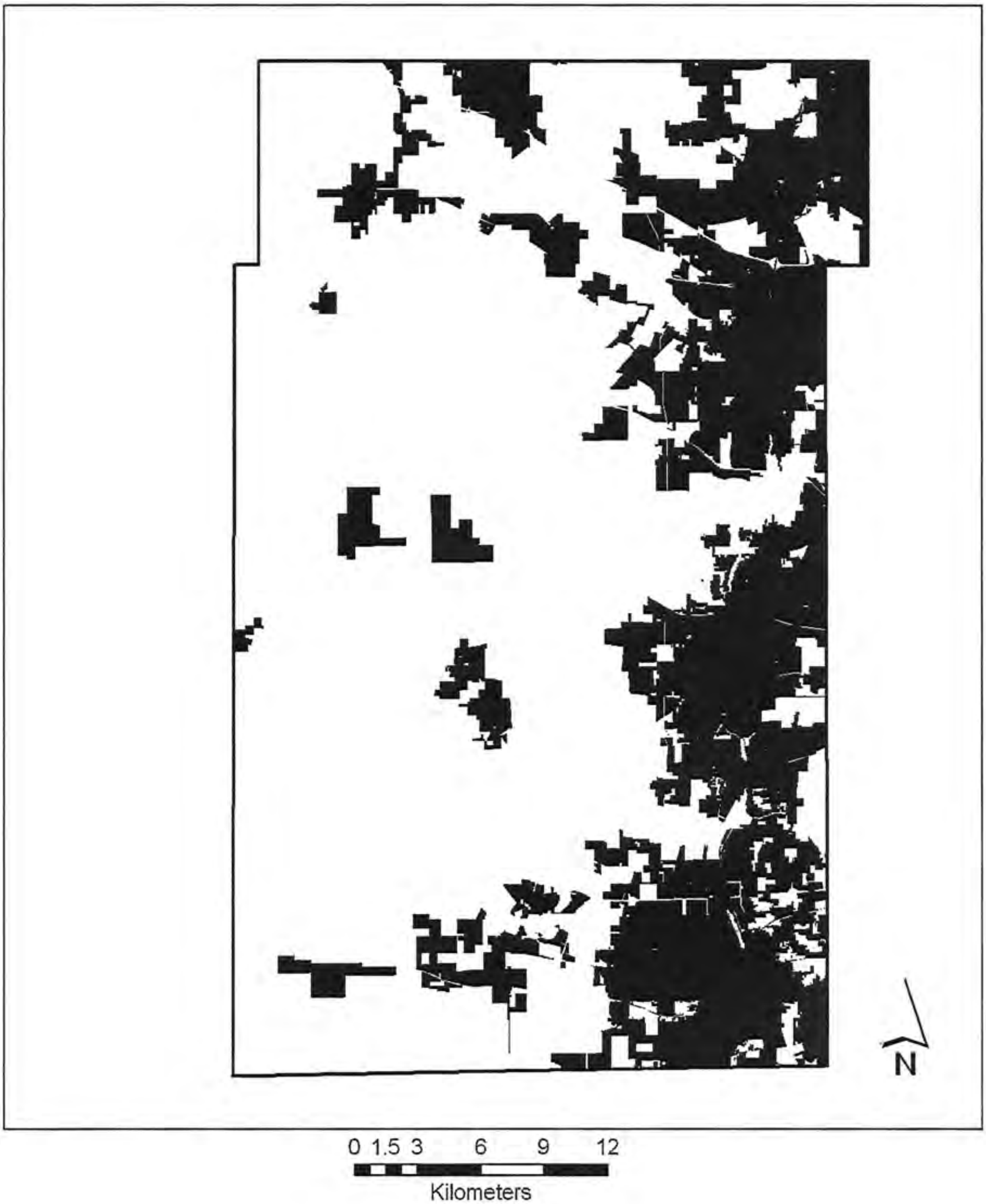


Figure 7. An average of urban growth outputs from all scenarios to show expected urbanized area in 2030.

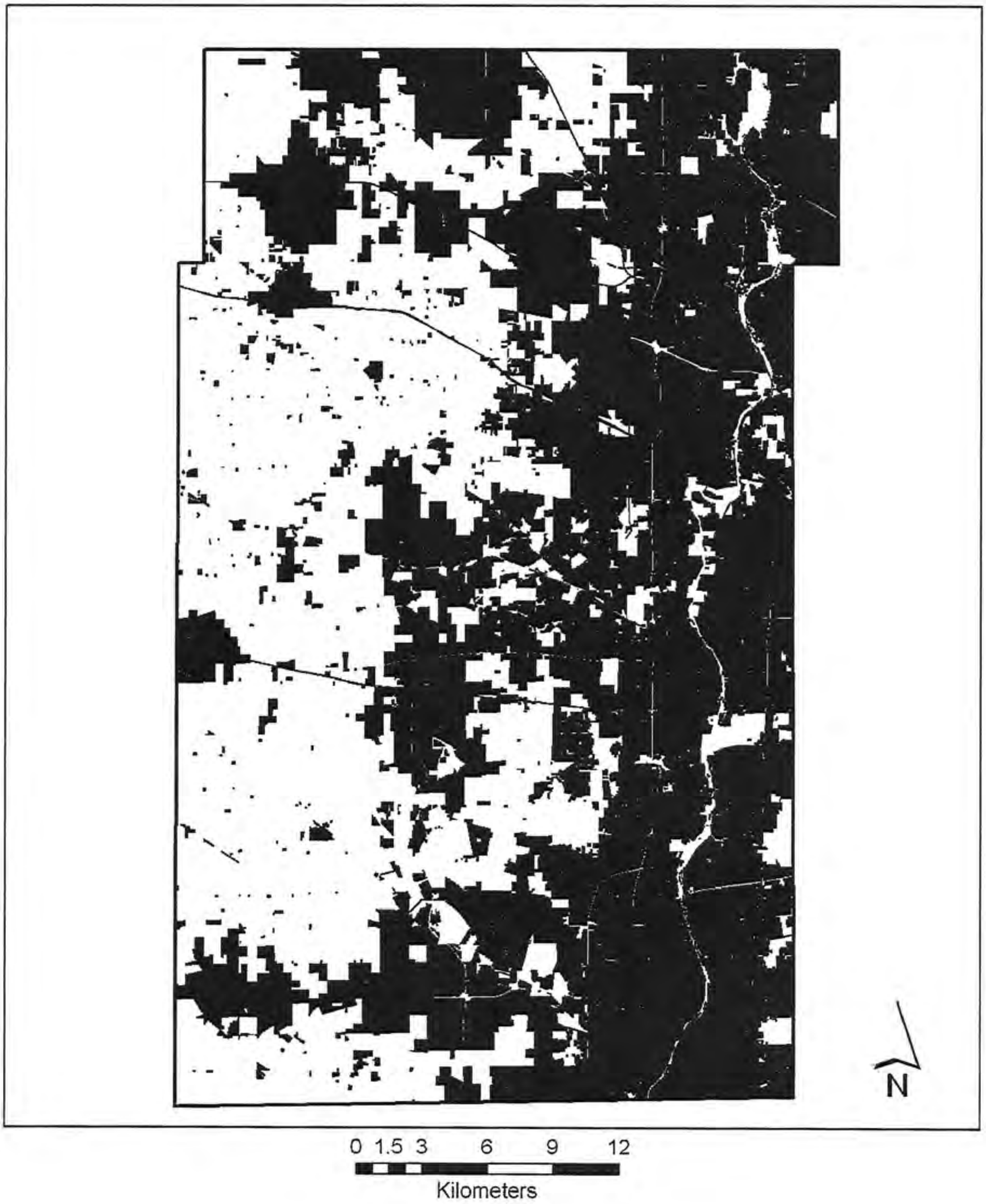


Figure 8. Expected land costs based on gradient of urbanization applied to each time step. Figure shows expected land costs for each of the county's 10 vertical sections, for each five year interval from 2005 to 2030.

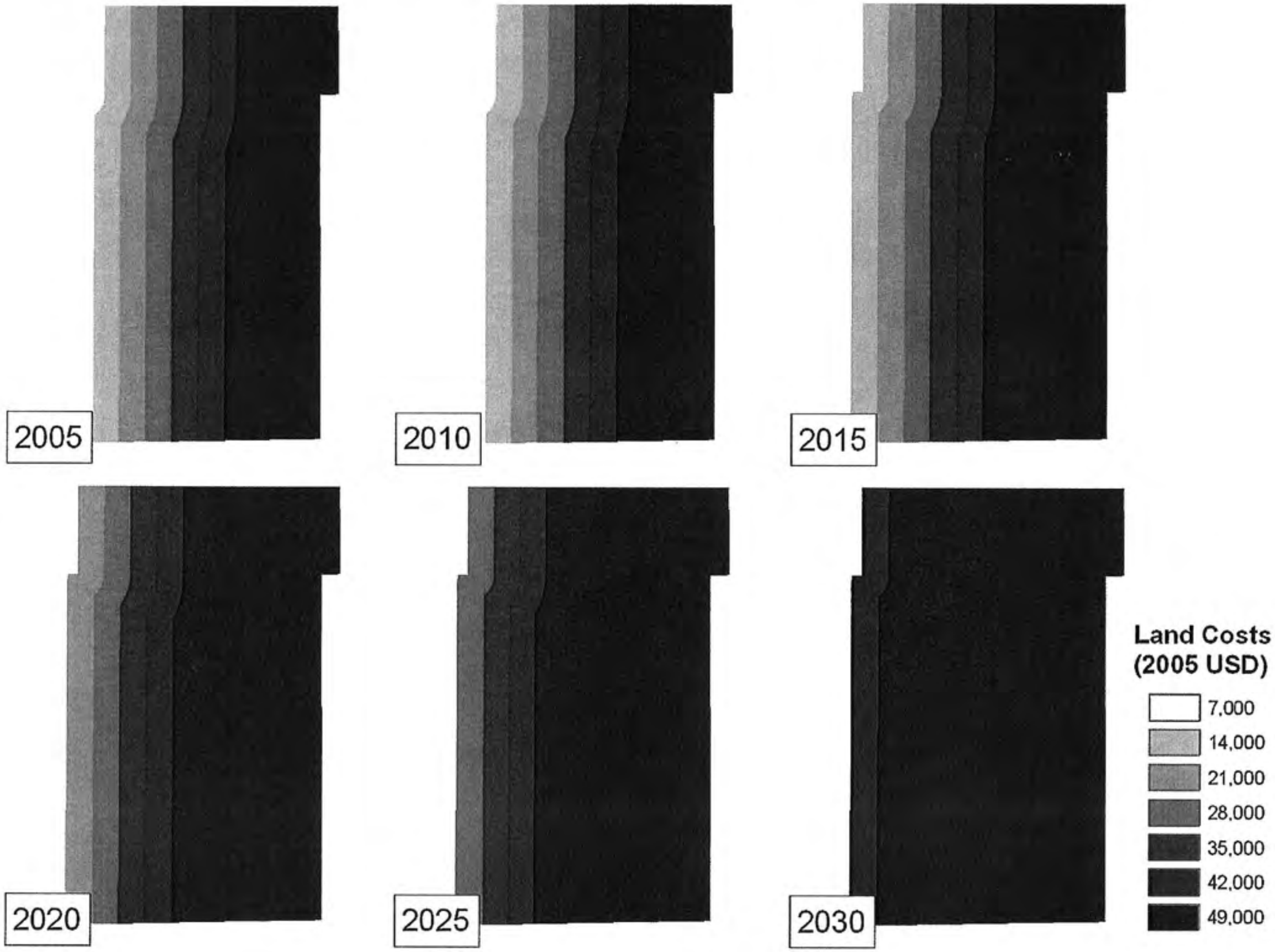


Figure 9. Results of all *high* scenario outputs for total open space for the year 2030.

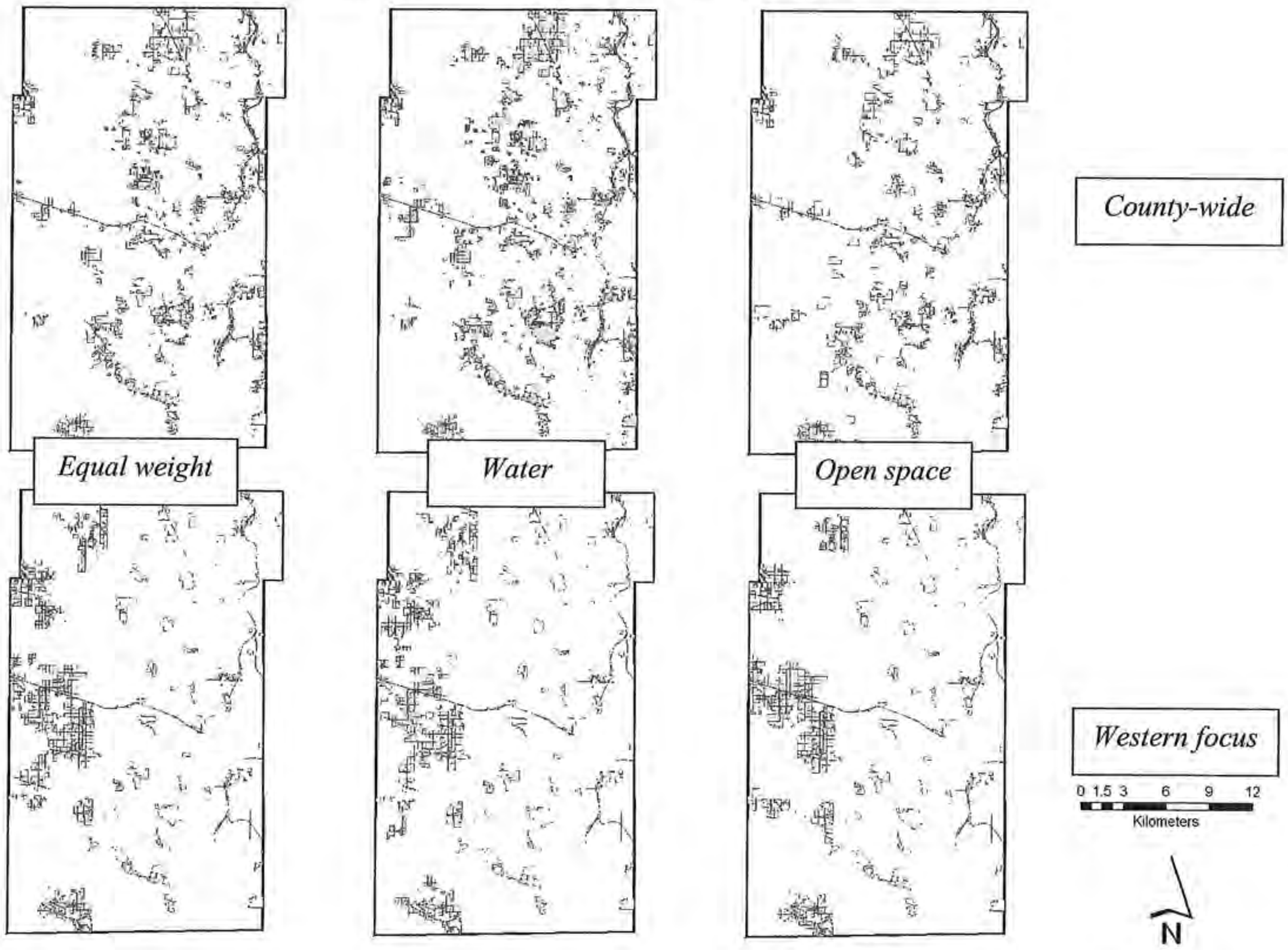


Figure 10. Results of all *trend* scenario outputs for total open space for the year 2030.

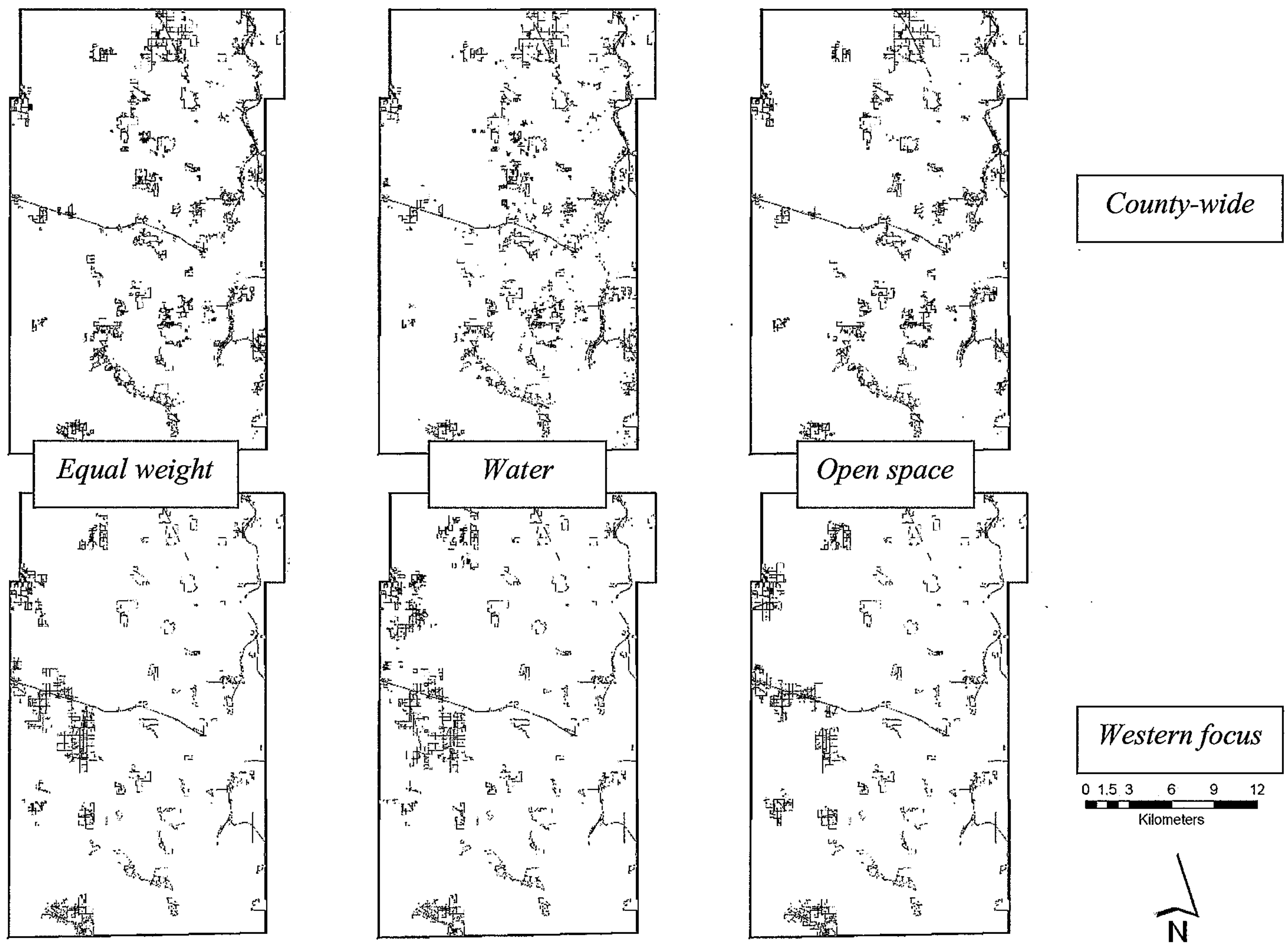
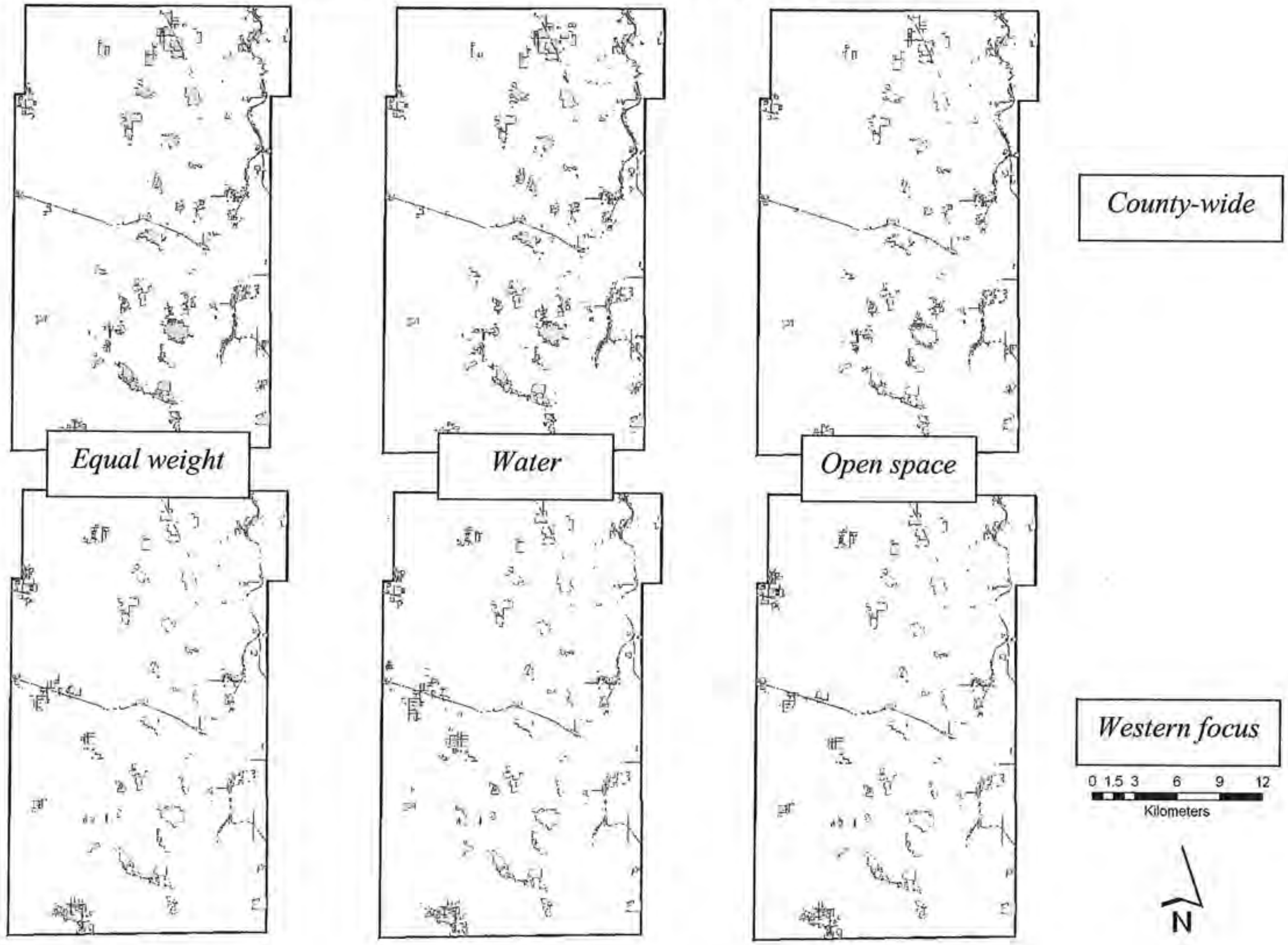


Figure 11. Results of all *low* scenario outputs for total open space for the year 2030.



CHAPTER 4. GENERAL CONCLUSIONS

Due to the outward expansion of the greater Chicago Metropolitan area, Kane County has experienced rapid increases in land consumption and property values. The county's Forest Preserve District is actively purchasing open space (Kane County 2005), but it is important to understand fully the long-term benefits and financial costs associated with specific goals to determine how best to plan for the future of open space in Kane County.

We created 18 future scenarios to identify costs associated with acquisition, restoration, and long-term maintenance of conservation lands in Kane County. These scenarios were evaluated in an alternative futures framework we created using ArcGIS which considered both conservation goals and urban growth. From these futures we were able to identify several trade-offs between scenarios for cost, quantity, and location of open space.

Our results indicate that there are several trade-offs that can be made between conservation goals that will substantially impact the future extent of open space in Kane County. Long-term costs were found to be lower in the western section of the county, where land is less developed and not as expensive. In addition to differences in monetary costs, other trade-offs were identified depending on specific goals for open space acquisition in Kane County. Focusing on areas with more available land allows the possibility of building larger core reserves, which may provide better habitat for some species (Herkert et al. 2003). We were also able to identify a trade-off between restoring acquired open space immediately versus focusing all available funding on expanding acquisitions. This is especially important in an area with extreme development pressures, as money would be available to acquire land before it is urbanized.

These trade-offs present interesting questions to planners, and although some of these may be considered currently, they are not being done so strategically. Long-term open space acquisition and conservation plans may require more thought on how to achieve specific goals of the organization and how to implement strategies to best achieve those goals. In addition to the application of our method to Kane County, the results of our project will foster explicit consideration of the long-term costs associated with conservation strategies in similar urbanizing regions in the United States.

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APPENDIX A. ADDITIONAL COMMENTARY ON GIS METHODS USED IN ALTERNATIVE FUTURES MODELING

1. Introduction

This section includes information on specific methods used in the design and modeling of alternative futures for Kane County, Illinois. This section goes into depth on specific GIS methods used in my research not presented in the body of my thesis. Included is information on data requirements and preparation, tools used in ArcGIS (ESRI 2005), and other analyses done to complete the research. Additionally, information is provided on Modelbuilder, the internal modeling interface of ArcGIS, and how it was used to streamline analyses.

2. Data Preparation and Tools

2.1. Project Setup and Data Requirements

Data were prepared for modeling using several ArcGIS components including ArcMap, ArcCatalog, and ArcToolbox. ArcMap was used to visualize and modify data, while ArcCatalog was used to create and populate all geodatabases. ArcToolbox provided the additional tools for data manipulation and analyses.

All spatial data, models, and tools were stored in an ArcGIS geodatabase. A toolbox was created for each geodatabase to store models and ArcToolbox tools. All tools used in the modeling process, with the exception of selection, joining, and exporting tools, were found in ArcToolbox and imported into the Toolbox within the working geodatabase. The selection, joining, and exporting work was done in ArcMap, as these processes required some level of supervision. Additionally, geodatabases automatically calculate and update areas of individual polygons within a feature class, a time-saving step for this method. Two geodatabases were created for each model, one for intermediate derived data, input data, models, and tools, and the other for baseline and end run data outputs.

Data requirements for this project include county parcel data, parcel zoning information, location of water bodies within the county, and the location of existing Forest Preserve District open space within the county (KCGIS 2005). Additionally, estimates of urban growth over time were needed to calibrate the urban growth model. It was not the intent of this project to predict urban growth, but rather identify possible locations of development based on pre-defined growth expectations. For "urban" and "non-urban" land cover classification, parcel data were used due to the lack of availability of recent land cover data. Zoning information in the parcel data were translated to represent developed or undeveloped parcels.

2.2. Data Preparation

Each parcel required a unique identification number so that its identification could remain constant over time. The parcel data included a unique ID in the form of a "Parcel Identification Number" or "PIN", which was the unique parcel identifier assigned to each parcel for identification by the county. With future work, or application of model outputs to the real world, the PIN is a standard that will help identify specific locations within the county.

In addition to spatial data preparation, it was necessary to prepare the urban growth estimate information for use over time. Based on estimates predicting an increase in urban development from 16% to 52% between 1998 and 2028 (Openlands 1999), these growth estimates allow calculation of the expected developed land cover in any year between 2005 and 2030. Developed growth was assumed to increase at a constant rate, and calculated to

4%, where it would be compounded annually. This information was then used to define how much land would be consumed by development per five-year time step between 2005 and 2030. Those data were then used while selecting the quantity of suitable parcels to be added on each subsequent urban growth time-step.

2.3. Key Tools

"Euclidean distance" is a spatial analyst function that returns relative distances to features in the source layer. The outputs show areas nearest to the features with the lowest weight. By design, this project requires the most suitable areas have the highest weights. To remedy this, every time that a Euclidean distance output is reclassified using the "Reclassify" spatial analyst tool it was necessary to use the "reverse sorting" button on the reclassification dialog box. If this is not done, the resulting output will be the inverse of the desired effect, and the results will not be accurate. In addition, all reclassifications are based on the "Equal Interval" principal. Equal interval is an option within reclassify which divides the input into equally spaced classes dependent on the size of the input and the desired output values of the reclassification. It is important that reclassification be done every time because not all inputs are the same, which would impact the accuracy of the reclassified outputs.

In addition, the spatial analyst commands "Plus" and "Zonal Statistics" were frequently used. The "Plus" function was used when adding reclassified raster data sets together to create a suitability raster layer. The zonal statistics function was then used on the resulting raster suitability outputs with the unique ID set as "PIN" and the "Zone" dataset defined as the available parcel layer. For all zonal statistics outputs, the "Mean" field is the field that represents suitability for a given parcel. The mean field is the average suitability value of a parcel based on the value of every raster cell it overlaps. This allows for those parcels that have the best suitability overall to receive the highest weights.

3. Additional Methods

3.1. Parcel Availability

The initial step in the modeling process was to identify "available" parcels. "Available" refers to those parcels which are not currently zoned as "developed", or owned by the Kane County Forest Preserve District. Parcels were broken down into residential, commercial, industrial, agricultural, and exempt. The residential, commercial, and industrial parcels were grouped together and labeled "developed" whereas agricultural and exempt parcels were labeled "available", meaning available for open space acquisition or development. "Exempt" layers were included in the "available" layer, as the extended information was not sufficient to identify specific uses of each "exempt" parcel.

To determine available parcels, the "Select by Location" tool in ArcMap was used to select any parcels that were "contained by" polygons in the 2005 Forest Preserve District Conservation Lands baseline layer. Those parcels were then removed from the parcel layer so that they would not be duplicated in future acquisitions. Using the "Select by Attributes" tool, parcels labeled "developed" were selected and then exported to the geodatabase as a new feature class, "Urban_2005", or the 2005 urban baseline. The "Switch Selection" tool was used to invert the selection so that the remaining "available" parcels would be selected. This selection was then exported to create the baseline 2010 "available" layer which, based on the assumption of this project that urban development will occur prior to open space acquisition, reflects the parcels which would be available for new development in 2010. Once 2010 develop layers were identified, they were removed from the available layer such to create a new available layer for open space acquisition. This process was continued in five-year iterations until 2030.

3.2. Deriving Static Inputs

Proximity to water bodies, proximity to municipalities, and the western tier are raster inputs that are static in nature. They do not need to be calculated in each model, as it increases the complexity and time necessary if they were derived with each model run.

Proximity to water bodies was derived using the Euclidean distance function on the water bodies input polygon layer. The output was then reclassified to 67, 50, and 33, or the three levels of influence proximity to water would have in different models. The analysis was nearly identical for the municipal areas layer, with focus being on reclassification of the Euclidean distance output. The main difference in the municipalities layer was that it was reclassified to 32, and areas that contained "no-data", or areas inside of a given municipal area, were given a value of 33. Because "no-data" reflected those areas currently existing in a municipal boundary, as it was to be the highest value, 33 was assigned to it after the remainder of the layer had been reclassified.

The western tier raster layer was needed for use in the tertiary scenarios. The western tier is comprised of the townships in the western third of the county (Figure 4). Using a polygon layer of the counties townships, I added a field to reflect "tier weight". To reflect the requirements of the secondary scenarios, the western most group of townships were given a value of 25, and the remaining two thirds of the county were given a zero value. Using "Feature to Raster" this layer was converted to a raster file where the resulting raster output weighted the western third of the county 25, and the remaining two thirds a weight of 0.

3.3. The Models

Two models were developed for the purpose of this project, an urban growth model and an open space suitability model. The urban growth model assumes that development will occur in areas proximate to existing urban areas, as well as areas inside of and proximate to municipally annexed land. Areas proximate to existing urban receive a 2:1 weight (67 points), and areas in or surrounding municipalities receive a weight of 1:2 (33 points). The open space suitability model focuses on proximity to existing open space and proximity to water bodies, and uses the assumptions defined by the scenarios for open space conservation. These models work in tandem with each other and were completed in five-year time steps starting between 2005 and 2030.

These models comprise a series of processes were completed using ArcGIS 9.0 (ArcToolbox, ArcCatalog, ArcMap, and Modelbuilder) and Microsoft Excel. To aid in the automation of these models, five ArcGIS Modelbuilder models were constructed to streamline the modeling process. These Modelbuilder models (MBM) should not be confused with the larger models, as they are only a means of automating parts of the analyses. This method does not allow for all analyses to be done strictly in ArcGIS.

3.4. Modelbuilder Models (MBM)

There were 5 MBMs constructed to aid in analysis. By creating these sub-models it allowed for a more streamlined modeling process. The use of MBMs allowed processes to be strung together in sequence instead of having to run each process individually. Additionally, dialog boxes were created so that inputs and outputs could be defined easily.

The initial 2 MBMs were simple models completing a Euclidean distance function for either urban growth or open space acquisition. It was necessary to derive Euclidean distance outputs prior to inclusion in a model with reclassification, as the models were found to be inaccurate when they were run in sequence. The remaining models consisted of a conservation suitability model, an urban growth model, and a table preparation model.

Upon creation of a MBM, "Environmental settings" were set to help standardize outputs including scratch and workspace settings, default raster cell size, and extent. Extent was set to reflect the boundaries of Kane County, as outputs were not required outside of this area. The default cell size was set at 30 meters. This cell size was chosen because larger cell sizes, although faster to derive, had problems deriving zonal statistics. Larger cell sizes limit statistics on very small zones, or in this case parcels, from being calculated.

An important aspect of an MBM is the ability to set model parameters and variables. Any input, intermediate data, output, or variable can be set as a parameter. When this is done, upon running the MBM, these items will appear in the dialog box and allow for easy modification for the user. Any variable that is necessary in the model run can be parameterized so that it is included in the model dialog box. These can be added to the MBM by right clicking on the tool and selecting "add variable from environment". This will allow for easier control and much faster manipulation.

The urban Euclidean MPM simplifies the process of deriving a Euclidean distance output for a given input (Fig. 1). The input and output fields were parameterized so for each run of the file I was prompted to enter the input and output fields. The Euclidean output from the previous model was used as the input for the urban growth MBM. Unfortunately, Modelbuilder did not work properly when the Euclidean distance function was followed by a reclassification; therefore these two models had to be split.

The urban growth MBM helps identify "priority" areas for growth to occur within the county (Fig. 2). This model reclassifies the urban Euclidean output, adds municipality influence, and calculates zonal statistics on the available parcel layer with respect to the "suitability" output. The resulting output is also a zonal statistics table to show suitable areas for growth to occur.

The conservation suitability MBMs are very similar to the urban growth MBMs. The first, the Euclidean MBM (Fig 3.), performs identically to the urban Euclidean MBM. The conservation suitability MBM is slightly different in that the scenario being modeled must be considered and relative inputs must be chosen accordingly (Fig. 4). For instance, when running a scenario that weights proximity to existing conservation lands 2:1 over proximity to water bodies, the conservation Euclidean input must be reclassified to 67, and the water bodies input must be the one reclassified to 33. The final output for this model is a zonal statistics table.

The table preparation MBM was designed to clean and help automate some calculations necessary for the modeling process (Fig. 5). This particular tool is to be used after the initial data joining and exports in ArcMap. It removes several unnecessary fields from the data set to allow for an easier working environment. Additionally, it creates fields for "hectares" and "Total Hectares", two necessary fields, and computes the "Hectares" field based on the shape area field.

3.5. The ArcMap Operations

The ArcMap operations were broken down into two sets depending on their position in the modeling process. The initial ArcMap operations included setting up a spatial "Join" between the zonal statistics outputs and available parcels layers which were exported as tabular data. This "Join" was done using the "PIN" field as the field in both of the layers. After joining data, the attribute table was exported to a new database file (.dbf) to be used as the input for the table preparation MBM. After exporting the join was removed to prevent adding irrelevant data to future sets.

The final ArcMap operations were done to join, select, and export the suitability information with the parcel information. The operations derived the final outputs for a given time-step, open space suitability or urban growth, and include a spatial "Join" as well as selection and exportation of spatial data layers. The "Join" was done using the "PIN" field from both the input tabular data as well as the available parcels layer.

After the files were joined, the most suitable parcels, or those to be added to either urban or open space, were selected from the layer using the "Select by Attributes" tool in ArcMap. The selection was based on the "Total Hectares" field which was previously calculated in Microsoft Excel, as well as the pre-determined hectares required for the given time step. This number reflects either the urban growth assumptions, or in the open space conservation model, the primary scenario being modeled. Because parcels are static bodies with specific sizes, an assumption was made that selection of parcels would up to but not exceeding the pre-determined acre requirement. After selection of the suitable parcels the spatial join was removed to prevent exporting of unnecessary data. The selected polygons were exported to two new geodatabase feature classes, i.e. in the urban 2010 growth model they were called Urb_2010_add and Urb_2010. The "add" feature class was kept as a record of which parcels were added during a given time-step. The other was used to append the previous time-step outputs to provide a complete representation of all areas in a given year.

Once these are exported, choose the "available" layer again and use the "Switch Selection" command. The new selection includes all parcels still deemed "available" as they were not removed from the previous urban model. This selection is then exported as the next model's available layer, i.e. if the completed model was Urban 2010, then this available export will be called "Con_Avail_2010", which will act as the available parcel layer for open space acquisition in the 2010 time-step.

3.6. Excel Analysis

After completing the initial step of ArcMap operations it was necessary to edit the resulting .dbf in Microsoft Excel, as ArcGIS was incapable of doing this particular analysis internally. The .dbf was opened in Excel, being careful not to change the structure or to save it as another file type, either of which may comprise the table and not allow it to work in ArcMap. Suitable areas are determined as those with the highest "Mean" zonal statistic, or highest average parcel suitability rating. All columns were selected, were sorted "descending" based on the "Mean" field with the "header" option clicked. This sorting placed the parcels in order of suitability from highest to lowest.

The "Total Hectares" was calculated as it determines which parcels are "developed". The "Total Hectares" cell associated with the highest "Mean" value was selected and populated such that the "Total Hectares" field value is equal to the "Hectares" field value. Subsequent fields were populated such that the "Hectares" field value for each additional suitable parcel was added to the "Total Hectares" value of the previous most suitable parcel. After entering the formula for the first cell, the rest of the cells were automatically calculated. The file was then saved, and closed.

3.7. The Modeling Process

A key component to this project was not only to model urban growth and open space suitability, but also to incorporate these two aspects such that the output of one impacts the possibilities of the other (Fig. 6). It was assumed that, for a given time-step, urban acquisitions would occur prior to open space acquisitions.

The modeling process for urban growth or open space suitability models was identical with the exception of which MBMs were used. For a given model the Euclidean MBM was run first, followed by the suitability or growth MBM. The data were used in the initial set of ArcMap operations, exported, and then used as the input for the table preparation MBM. The data were then used in the Excel analyses and then used in the final set of ArcMap analyses. The resulting outputs for a given model include the parcels which were added during a given time-step, and those parcels which remain available for the subsequent model.

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Figure 1. Visual of the Urban Euclidean MBM, with corresponding dialog box, from ModelBuilder.

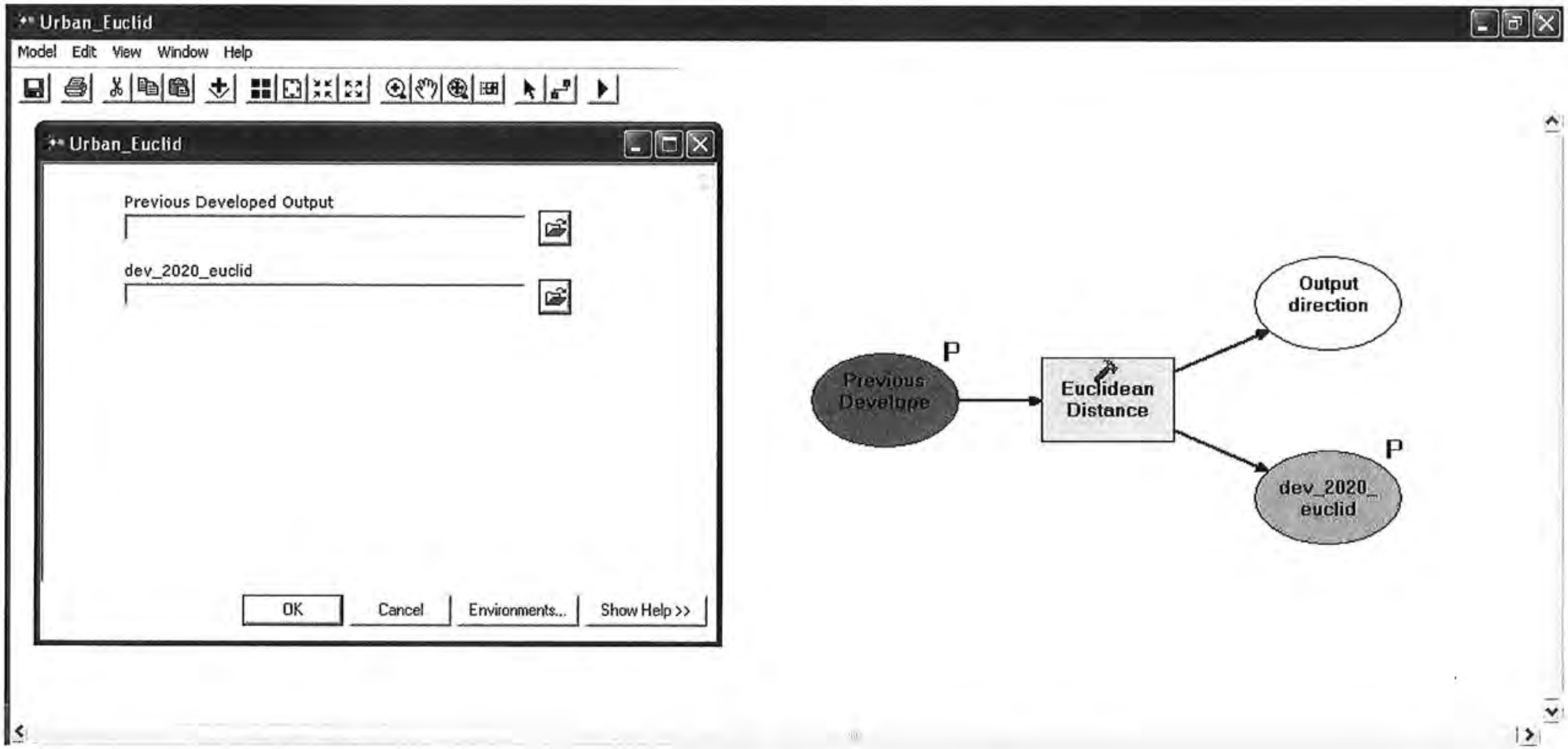


Figure 2. Visual of the Urban Growth MBM, with corresponding dialog box, from ModelBuilder.

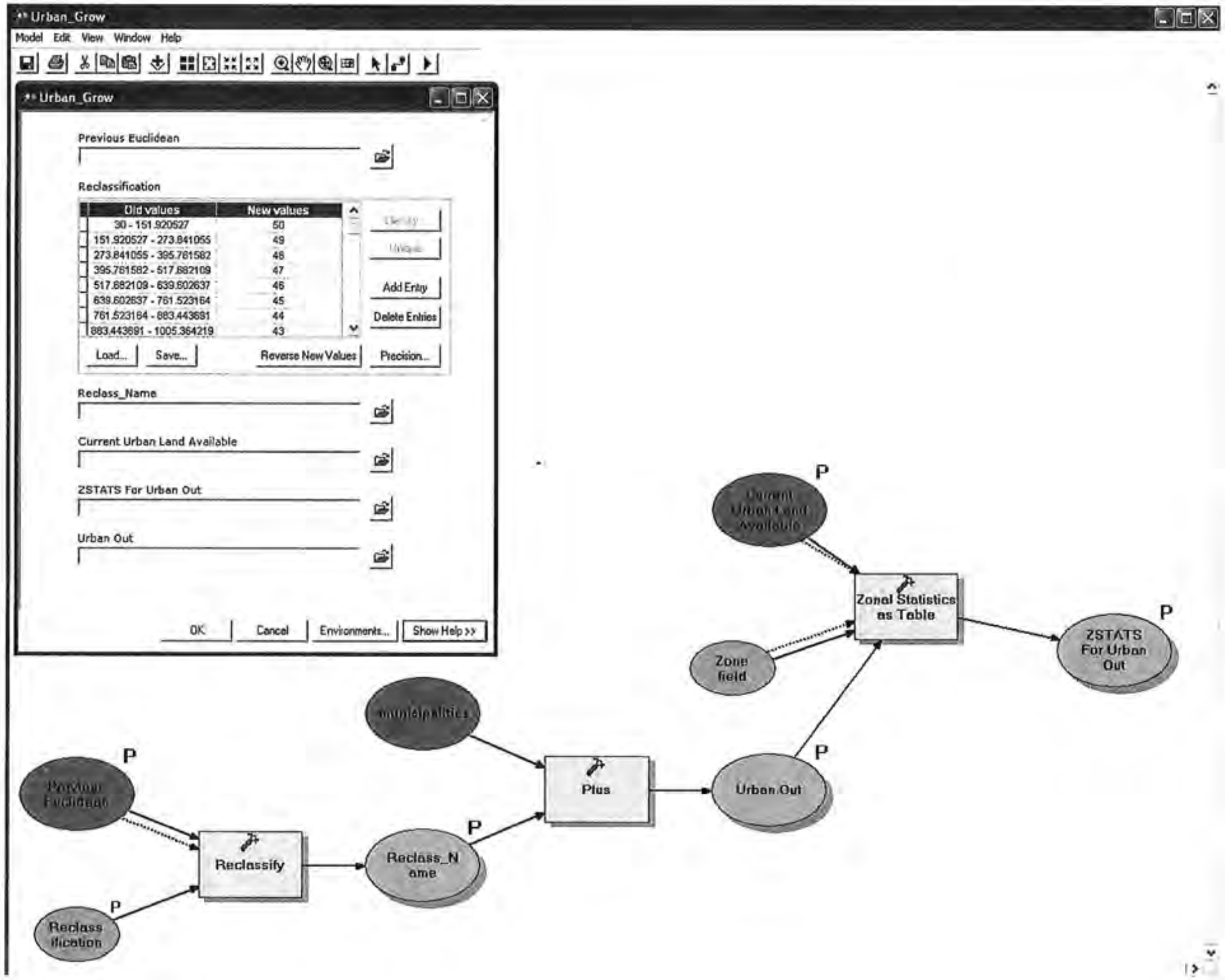


Figure 3. Visual of the Conservation Suitability Euclidean MBM, with corresponding dialog box, from ModelBuilder.

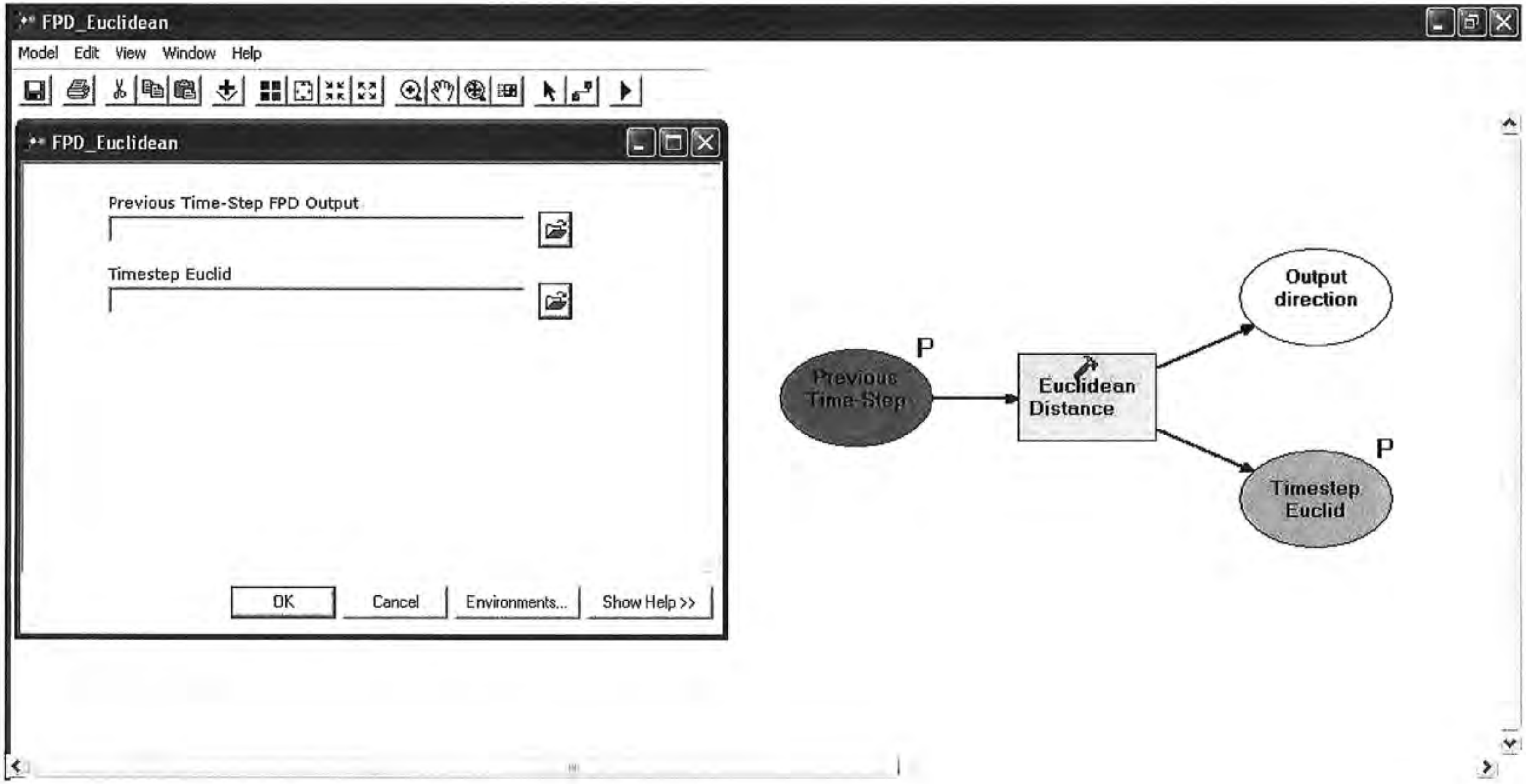


Figure 4. Visual of the Conservation Suitability MBM, with corresponding dialog box, from ModelBuilder.

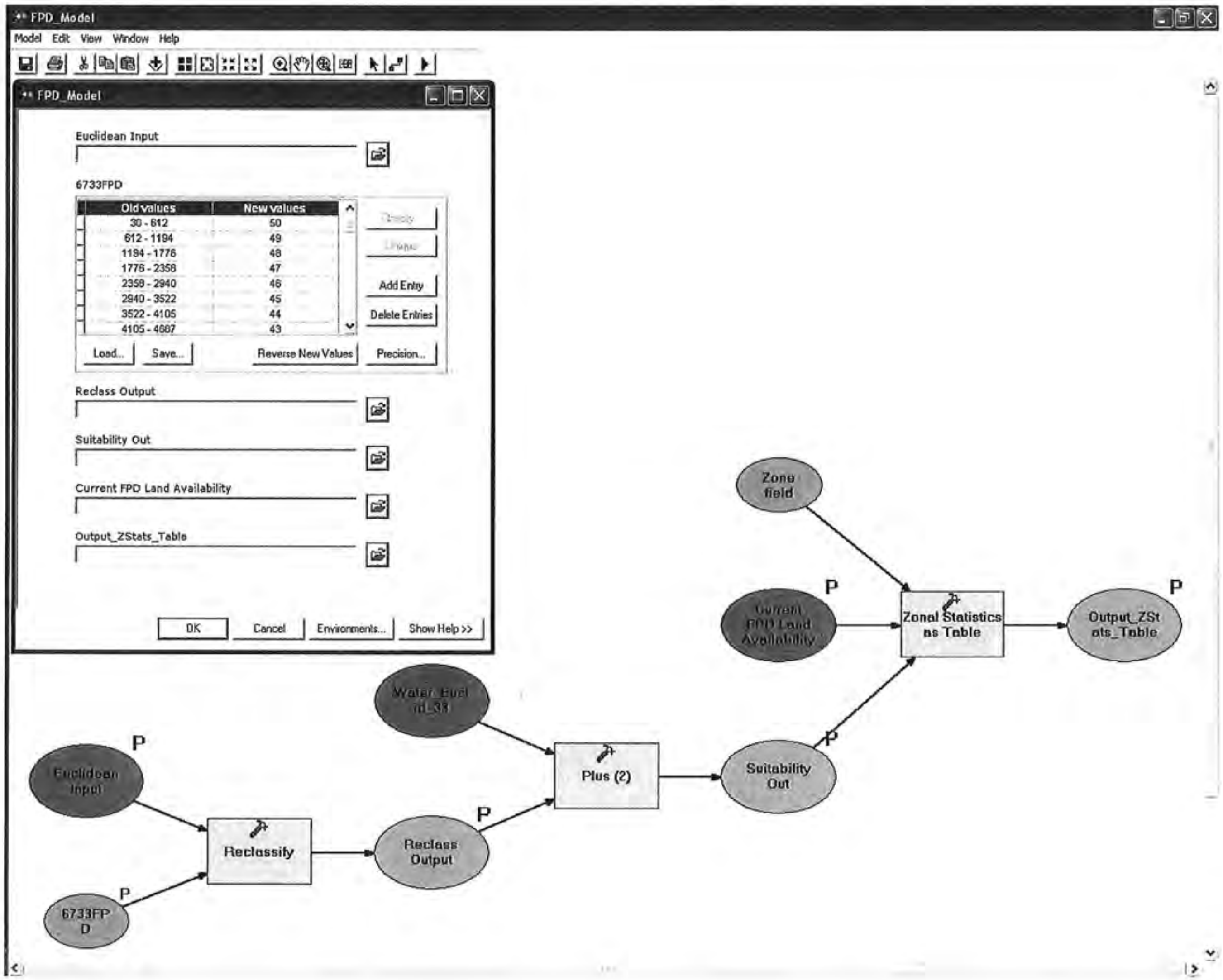


Figure 5. Visual of the Table Preparation MBM from ModelBuilder.

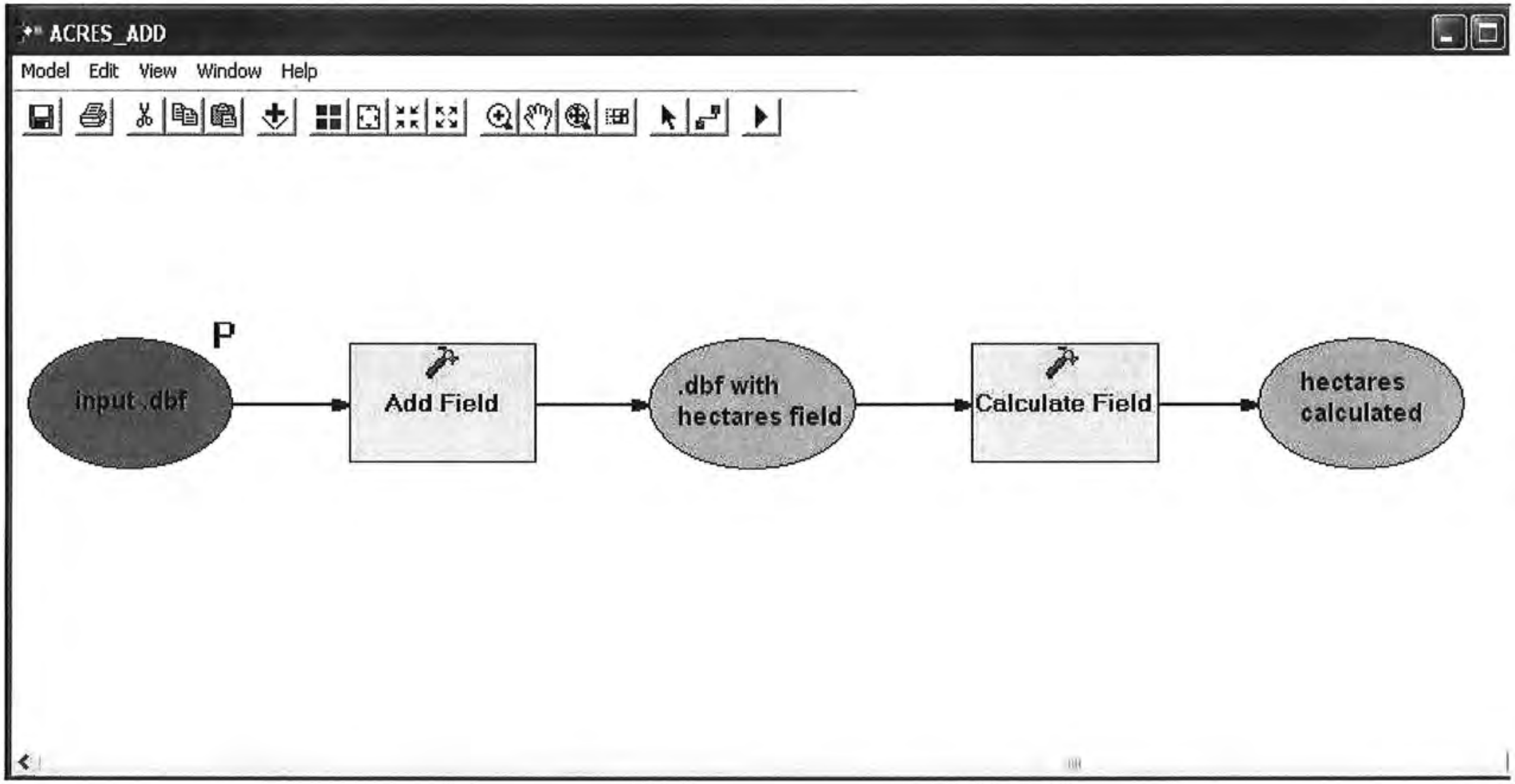
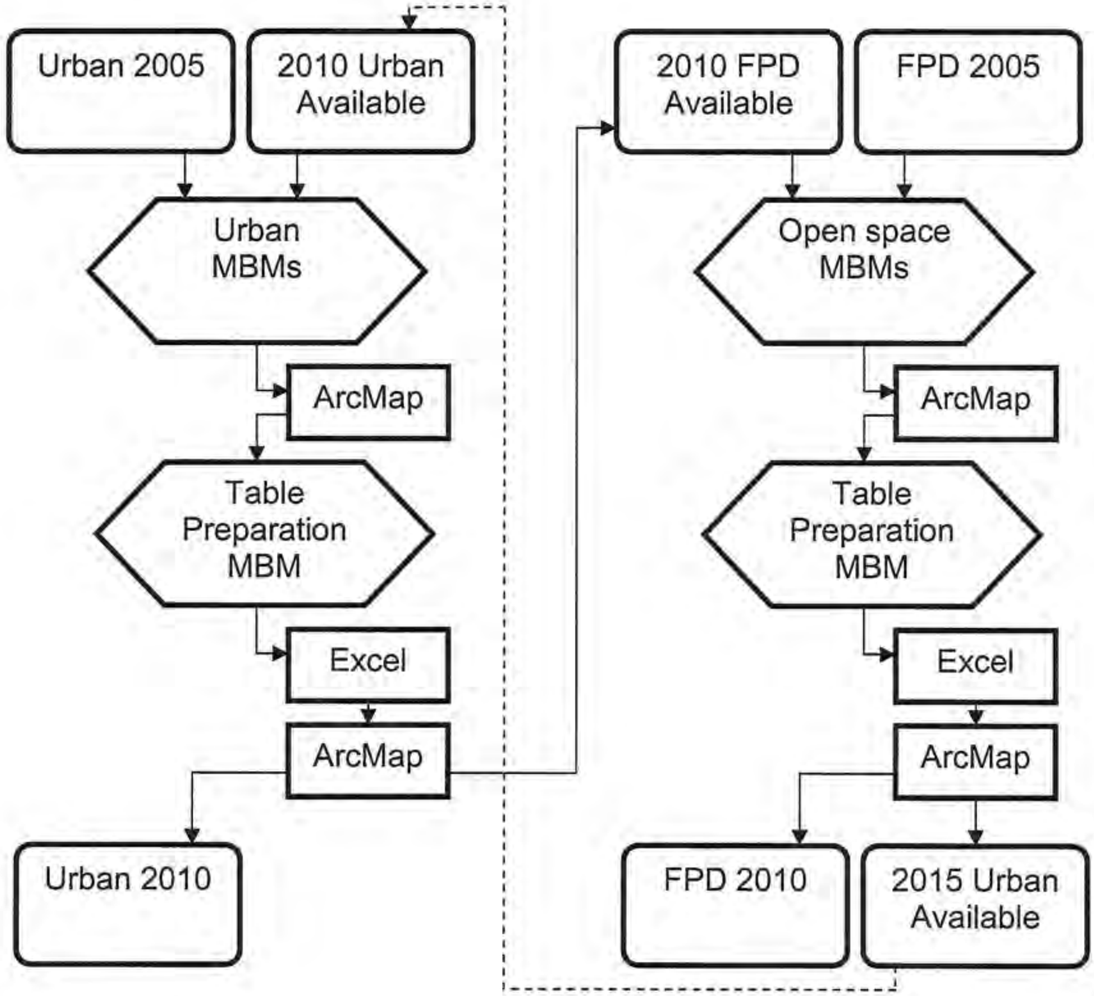


Figure 6. Modelbuilder model interactions.



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